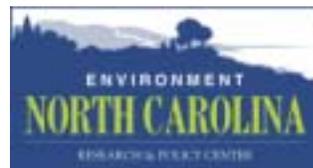


# Air Pollution and Public Health in North Carolina



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# Executive Summary

**A**ir pollution in North Carolina makes people sick and cuts lives short. Air pollution triggers heart attacks and strokes. It causes diseases like chronic bronchitis, asthma and lung cancer. It sends people to the emergency room with respiratory problems, causes asthma attacks, and contributes to respiratory illness in otherwise healthy people. At the root of all of these problems, air pollution irreparably damages lung tissues in ways similar to second-hand tobacco smoke.

In this report, we estimate the health impact of air pollution above natural background levels in North Carolina. The estimates cover particulate pollution (or soot), which comes from smokestacks and vehicle exhaust, and ground-level ozone (or smog), which develops across much of the state on hot summer days as a result of emissions from cars, trucks, smokestacks and other sources. The estimates rely on a number of information sources: 2003 air pollution monitoring data from the U.S. Environmental Protection Agency (EPA); statistics about the frequency of health problems from the North Carolina State Center for Health Statistics and the U.S. EPA; scientific studies linking air pollution and health problems; and methodology based on similar work from the U.S. EPA and the World

Health Organization. Taken together, these sources reveal that air pollution places a significant burden on the health of all North Carolinians.

**Many North Carolina residents suffer health problems caused by pollution even at levels that meet air pollution standards.**

- Despite the fact that air pollution levels in North Carolina meet health standards during much of the year, even “safe” levels of pollution can cause damage. Scientific experiments show no threshold below which pollution does not have an effect.

**Air pollution causes illness in otherwise healthy people.**

- Air pollution causes in the range of a half-million missed work days each year, and millions of cases where North Carolinians experience symptoms like shortness of breath or runny nose.

**Air pollution causes thousands of people to be admitted to area hospitals every year and increases the burden of chronic disease.**

- Air pollution leads to an estimated 6,000 hospital admissions for respiratory disease and 2,000 for cardiovascular disease annually.
- In addition, air pollution causes approximately 1,500 new cases of asthma and 2,500 new cases of chronic bronchitis in adults every year.
- Among asthmatics, soot pollution causes an estimated 200,000 asthma attacks annually, with an additional 200,000 caused by smog.

**Every year, air pollution kills thousands of people in North Carolina.**

- Air pollution causes about 3,000 premature deaths in North Carolina annually, accounting for between 3 and 7 percent of all deaths not caused by violence or accidents.
- Compared to national statistics, air pollution ranks as the third highest risk factor for premature death, behind smoking and poor diet/physical inactivity.
- Tables ES-1 and ES-2 provide a summary of the health impacts of air pollution in North Carolina, including central estimates as well as upper and lower boundaries of statistical precision.

**Children are especially vulnerable to the effects of air pollution.**

- Every year, air pollution causes dozens of infant deaths and hundreds of thousands of school absences due to illness. (See Table ES-3.)
- Injuries caused by air pollution in early in life can have permanent consequences.

**Aggressive action to reduce air pollution can improve public health and reduce the societal cost of pollution-caused illness.**

In 1999, the two largest sources of North Carolina's air pollution were coal-fired power plants and automobiles. In 2002, the

state Legislature passed the Clean Smokestacks law, which will reduce power plant pollution in-state by more than 70 percent over the next seven years. Reducing pollution from vehicles is the next priority step toward healthy air at the state level. Because emissions from vehicles and industrial facilities located upwind from North Carolina also contribute to the overall problem, action at the regional and federal level will also be required.

**State Level Actions:**

- Strengthen limits on automobile air pollution in line with New York, Massachusetts, New Jersey, Connecticut, Rhode Island, Maine, Vermont, California, Oregon and Washington.
- Require retrofitting of diesel engines with particulate filtration systems, including school bus fleets and construction equipment.
- Reduce car-dependent land use practices and sprawl.
- Increase transportation funding for transit, rail freight, and other alternative transportation projects.

**Federal and Regional Level Actions:**

- Fully enforce the Clean Smokestacks Act, pursuing all available means to reduce pollution in neighboring states.
- Restore the New Source Review provision of the federal Clean Air Act and require the oldest coal-fired power plants and other industrial facilities in the country to install modern emissions control technology.
- Limit nationwide industrial emissions of sulfur dioxide, nitrogen oxides, and mercury to between 10 percent and 30 percent of 2000 levels.
- Strengthen national emission standards for cars and trucks to match or exceed standards adopted by California and other states.

**Table ES-1: Annual Public Health Damage from Smog (Ground-Level Ozone) in North Carolina**

Health Effect	Estimated Cases	Range
Adult Onset Asthma (Males, 25+)	1,500	900 – 1,900
Respiratory Hospital Admissions	4,000	3,000 – 5,000
Asthma Attacks	200,000	100,000 – 300,000
Restricted Activity Days	1 million	800,000 – 1.4 million
Increased Symptom Days	4 million	2 million – 6 million

**Table ES-2: Annual Public Health Impact of Soot (PM<sub>10</sub>) in North Carolina**

Health Effect	Estimated Cases	Range
Premature Death (Adults)	3,000	2,000 – 4,600
Respiratory Hospital Admissions	2,000	1,700 – 2,600
Cardiovascular Hospital Admissions	2,000	900 – 2,500
New Cases of Chronic Bronchitis	2,500	260 – 4,400
Asthma Attacks	200,000	100,000 – 390,000
Missed Work Days	500,000	440,000 – 520,000
Restricted Activity Days	5 million	4.1 million – 5.5 million
Increased Symptom Days	15 million	7 million – 23 million

**Table ES-3: Annual Air Pollution Damage to Children’s Health in North Carolina**

Health Effect	Estimated Cases	Range
Infant Deaths	50	30 – 60
Asthma ER Visits	1,500	200 – 3,500
Acute Bronchitis	20,000	13,000 – 33,000
Asthma Attacks	100,000	90,000 – 120,000
Missed School Days	300,000	NA

## How to Interpret Health Effect Estimates

The numbers reported here are an illustration of the likely health impacts of air pollution commonly found in North Carolina. The estimates are subject to several sources of scientific uncertainty, which could make the actual numbers higher or lower. Where possible, we attempted to make conservative assumptions—meaning the scope and scale of the impacts of air pollution may be larger than reported here. Sources of uncertainty include:

- The report does not capture or quantify all the effects of air pollution—for example, air pollution could affect development before birth, predisposing adults to disability or disease.
- The scientific studies that form the foundation of the estimates rely on statistical models that are sensitive to input assumptions.
- Health systems do not track events like asthma attacks, making frequency estimates necessary. These estimates may not reflect local conditions perfectly.
- Population exposures to air pollution are estimated based on readings at fixed monitors. Errors in extrapolating exposure to the whole population, either in this report or in published scientific literature, could affect the accuracy of our estimates.

See the methodology section on page 30 for a more complete discussion.

# Introduction

Air pollution in North Carolina is a serious and persistent problem.

The American Lung Association gives Charlotte, the Triad, the Triangle and the Asheville region an “F” for air quality—and that’s just for smog pollution.<sup>1</sup> Particulate pollution also poses major health risks for North Carolinians, especially children and the elderly.

Air pollution shortens lives, sends people to the hospital and the emergency room, and triggers asthma attacks. These are merely the most visible signs of the health threat posed by polluted air. Air pollution affects every individual, reducing lung function and increasing the risk of illness.

Nor are we safe on days when air pollution levels are below those recognized by government as meeting federal standards. Ozone smog and particulate soot can affect health even on days when an air pollution alert is not in effect.

This is especially true for people who live, work or play near busy roadways. The World Health Organization and the American Academy of Pediatrics recommend that communities take action to

reduce pollution—especially traffic-related pollution—to improve public health.<sup>2</sup>

It wasn’t supposed to be this way—not in 2006. When Congress adopted the federal Clean Air Act in 1970, it established the goal of setting and achieving air quality standards protective of human health by 1975. Nearly three decades later, North Carolina’s air still fails to meet established health standards—standards that may not be fully protective of human health.

With the rollback of key air pollution policies at the federal level—and with increased motor vehicle traffic, population, and overall energy use threatening to undermine the progress we have made toward cleaner air—North Carolina has reached a critical juncture. Solutions do exist. From modern emission controls for cars and power plants to effective transit systems, we have the technological know-how to significantly cut the amounts of air pollution in North Carolina air.

By adopting public policies that put these technologies to work, North Carolina can reduce air pollution and help millions of its citizens to live longer and healthier lives.

# Exposure to Air Pollution and How it Causes Harm

Most people think of air pollution only on days when the news announces an air quality alert, warning of high levels of smog. Unfortunately, people in North Carolina aren't exposed to air pollution just a few dozen times a year on bad air days. North Carolinians breathe air pollution day in and day out throughout their entire lives.

Much of the pollution comes from burning fossil fuels for energy—in cars, trucks, power plants, industrial facilities, and engines. Many of these pollutants are invisible, and they are everywhere. They mix together in the atmosphere and react in complicated ways to form a toxic soup.

On bad air days, visibility plummets and the air looks thick and hazy. (See Figure 1.) Sometimes the sun even looks red as it sets due to pollutants in the air. These clouds of haze contain hundreds of toxic chemicals.

Two of the most harmful air pollutants are soot and smog. Soot, or particulate pollution, contaminates the air year-round. Power plants, engines and motor vehicles emit soot directly into the air. Chemical reactions between gaseous pollutants in the air can also create fine particles. Smog

plagues summer days when intense sunlight transforms air pollutants and oxygen into toxic gases such as ozone.

**Figure 1: Clear and Polluted Days in Raleigh**



Photo courtesy of N.C. Division of Air Quality

*These two photos depict good and bad air quality days in North Carolina. Each photo depicts the same view from the WRAL tower off US 70 southeast of Raleigh near Clayton. However, in the second photo, visibility is greatly reduced by a cloud of smog containing ground level ozone and particulates.*

## Air Pollution in North Carolina

Smog and soot reach unhealthy levels regularly in North Carolina. Annual average soot concentrations in the state (measured as particulate matter (PM) less than 2.5 micrometers in diameter) range from about 8 micrograms per cubic meter in the least polluted parts of the state to 16 micrograms per cubic meter in the most polluted areas.<sup>3</sup> (See Figure 2.)

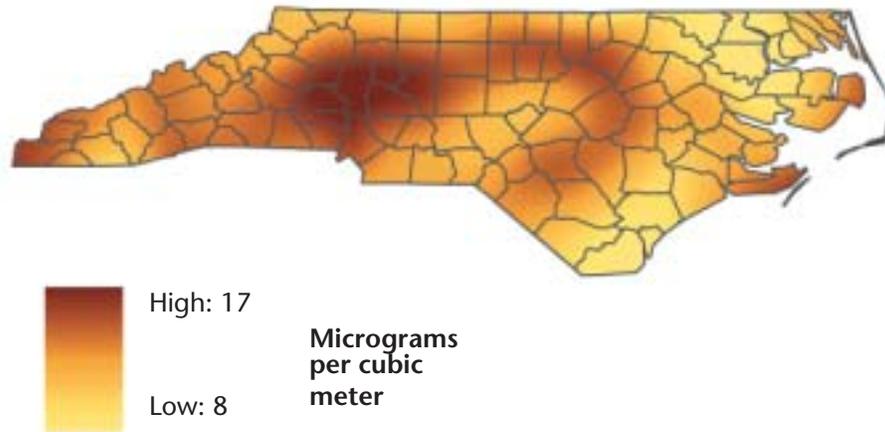
During the summertime ozone season from April through October, the average daily peak one-hour ozone levels reach

47-61 ppb across the state. (See Figure 3.) On hot summer days, ozone levels routinely exceed EPA health standards in the central part of the state.

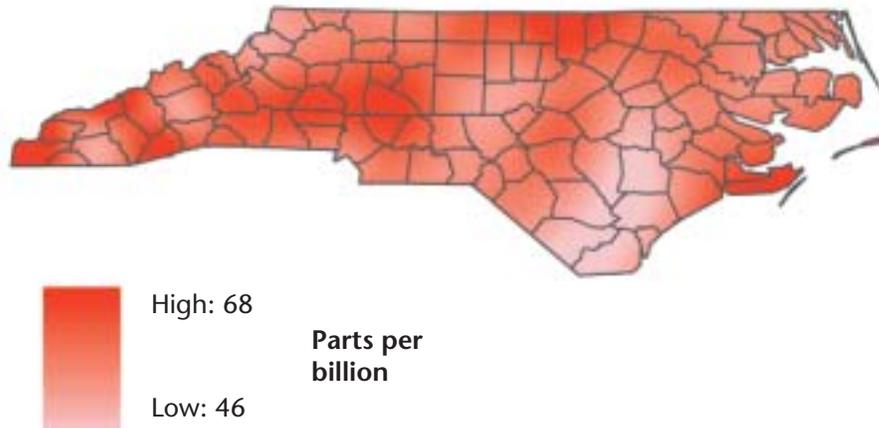
If there were no human-induced air pollution emitted in North America,  $PM_{10}$  levels would be between 5 and 10 micrograms per cubic meter, and afternoon smog levels in the spring, summer and fall would be 15 to 30 ppb.<sup>6</sup> If pollution were not emitted from other countries in the world as well, natural background levels would be even lower.<sup>7</sup>

Soot and smog cause damage when they come in contact with lungs. Ozone quickly

**Figure 2: Average Soot Levels in North Carolina, 2003 ( $PM_{2.5}$ )<sup>4</sup>**



**Figure 3: Average Smog Levels in North Carolina, April to October 2003<sup>5</sup>**



## Strengthening National Air Quality Standards

The Environmental Protection Agency (EPA) sets national air quality standards under the authority of the federal Clean Air Act. Under the law, the EPA is supposed to review the standards every five years and adjust them based on the latest scientific knowledge of what will protect public health with an adequate margin of safety.<sup>8</sup>

Because of industry resistance, the standards trail scientific understanding of how dangerous air pollution really is. For example, EPA tightened standards for both soot and smog in 1997, based on accumulating evidence that soot and smog were more harmful than previously believed. However, the American Trucking Association led a coalition of industries in a lawsuit against the new standards. Ultimately, the Supreme Court rejected industry arguments and upheld the standards in 2001.<sup>9</sup> The process delayed implementation of the new standards for years.

Researchers have published more than 2,000 studies on particle pollution since the last standard-setting review in 1997, showing serious health risks at pollution levels well below current standards.<sup>10</sup> In 2005, the independent Clean Air Scientific Advisory Committee and staff scientists at the U.S. EPA both concluded that the standards for particulate matter were not adequate and recommended strengthening them.<sup>11</sup>

However, the Bush administration disregarded the advice of these experts. In December 2005, the administration proposed standards weaker than recommended by its own scientists—ignoring their advice for the first time in history. As a result, the standards would leave millions of Americans exposed to particulate pollution at levels that pose clear risks to health.

reacts with airway tissues and produces inflammation similar to a sunburn on the inside of the lungs. Particulates travel deep into the lower passages of the lungs and become trapped there, delivering a payload of toxic chemicals. Constant exposure to these pollutants over time permanently damages lung tissues, decreases the ability to breathe normally, and exacerbates or even causes chronic disease.

### Soot (Particulate Matter)

Back in the early days of the industrial revolution, thick black smoke poured from factories and coal-fired furnaces. During the 1952 “Great Fog,” one of the most notorious pollution events in history,

12,000 Londoners died from intense pollution exposure.<sup>12</sup>

Today, the thick, black smoke characteristic of uncontrolled pollution has been replaced with the more subtle and insidious dirty haze that can almost look natural because of its frequent presence over the eastern United States. However, this pollution is anything but natural. It comes from fuel burning, and mostly consists of fine soot, or extremely small and practically invisible particles in the air.

Some types of soot are simply unburned fuel particles. Other types of soot are created when pollutants react with each other in the atmosphere. Particles can contain hundreds of different chemicals from cancer-causing agents like polycyclic aromatic hydrocarbons to metals from arsenic to zinc.

Forty to 1,000 times smaller than the width of a human hair, these fine particles result from burning fossil fuels like coal, gasoline, and diesel. For example, burning a pound of jet fuel creates 100 quadrillion particles.<sup>13</sup> Gasoline and diesel engines with and without catalytic converters emit particles with a size of 0.1 to 1 micrometers, with the smallest particles coming from gasoline and medium-duty diesel engines.<sup>14</sup>

Fine particles can remain suspended in the air for weeks. They can travel through building shells and conventional heating and air conditioning filters. When inhaled, they are able to penetrate deep into the lung where they deliver their toxic payload. In contrast, larger particles such as dust or pollen travel shorter distances and are more effectively trapped in the upper airway.

Fine particles penetrate to the deepest part of the lung, where they are attacked and absorbed by immune cells. In an experiment in England, ultra fine carbon particles showed up in the immune cells of every child tested—even in a three-month old infant.<sup>15</sup> The particles were of the same size emitted by motor vehicles, and children who lived close to busy roads had up to three times more particles in their bodies.

Some of the particles remain trapped in the lung, while others travel through the blood to the rest of the body.<sup>16</sup> Scientists have counted particulates in the lung tissue of cadavers. People from highly polluted Mexico City had two billion particles in every gram of lung tissue, and people from less polluted Vancouver, Canada had about 280 million.<sup>17</sup>

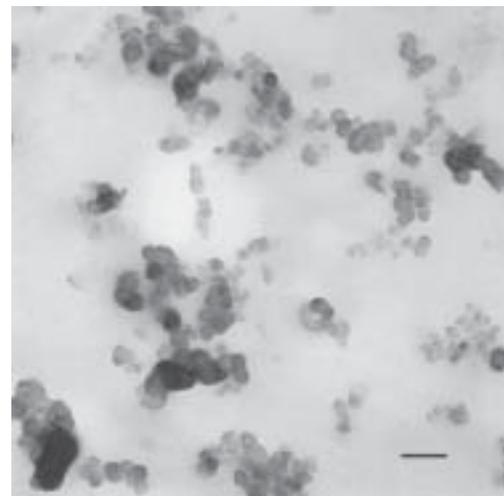
The chemicals delivered into the body by inhaled particulates are very dangerous. Some of them cause cancer, some cause irritation to lung tissues, and some cause changes in the function of the heart.<sup>18</sup> As a result, particulates cause and aggravate a host of health problems, including lung cancer and cardiovascular disease.

Particulate pollution can cause irreversible damage to children, interfering with the growth and development of the lungs.

For example, researchers at the University of Southern California followed the health of over 1,000 ten-year-olds until they reached 18. Children who lived in areas with higher levels of particulate pollution were less able to breathe with normal capacity.<sup>19</sup>

Particulate pollution is also deadly, killing upwards of 50,000 Americans every year. In fact, according to the largest study of the effects of particulates on mortality, breathing the air in major U.S. cities is about as dangerous as living or working with a smoker.<sup>20</sup>

#### Figure 4: Soot Particles



*Very small soot particles found in diesel exhaust.<sup>22</sup> The scale bar represents 10 nanometers.*

## Smog (Ground-Level Ozone)

Smog can plague summer days in North Carolina. Smog results when a mixture of pollutants reacts under intense sunlight to form ozone.

In the past five years, ozone levels in North Carolina have exceeded federal health standards on as few as 5 days and as many as 51, with an average of 25.<sup>23</sup> However, ozone chronically contaminates the air at lower, but still harmful, levels from April through October.

A natural layer of ozone exists high in the atmosphere, absorbing ultraviolet radiation from the sun. However, when pollutants create ozone near the ground, it becomes a threat to public health.

Ozone is a powerful chemical gas sometimes used to kill bacteria in drinking water. Bubbling it through contaminated water destroys any infectious organisms in the water and makes it safe to drink. Not surprisingly, the chemical has the same effect on our lungs—when inhaled, it damages lung tissue and causes short-term swelling. With long-term exposure at even low levels, it causes permanent and irrevocable damage.

Scientists have known for well over a decade that ozone at levels routinely encountered in North Carolina causes reddening and swelling and reduces the elasticity of lung tissues over time.<sup>24</sup> Ozone makes lung tissues more sensitive to allergens and less able to ward off infections.<sup>25</sup> It scars airway tissues. Children exposed to ozone develop lungs with less flexibility and capacity than normal. During high smog days, otherwise healthy people who exercise can't breathe normally.<sup>26</sup>

New scientific evidence continues to show dramatic evidence of the severe and long-term impact ozone exposure has on respiratory health:

- College freshmen who were raised in less polluted areas have lungs that

work better than their schoolmates who grew up in polluted cities. For example, University of California-Berkeley freshmen who have lived in places with less ozone pollution can exhale more forcefully than students from more polluted areas.<sup>27</sup> Yale freshmen who have lived for four or more years in a county with high ozone levels can't breathe as well as freshmen from cleaner areas.<sup>28</sup>

- Recent studies show that the lungs of asthmatic infant rhesus monkeys suffer irreversible structural damage when exposed to ozone.<sup>29</sup> Ozone exposure reduces the number of branches formed by nerves and airway passages in the lung and forces lung muscles to reorganize, and long recovery periods do not improve the damage. The immune system and cellular responses to ozone are like those seen with asthma. Dr. Charles Plopper of the University of California-Davis, the author of the studies, commented, "from a public health standpoint, it's a pretty disquieting situation."<sup>30</sup> Researchers believe the same damage happens to human infants when exposed to air pollution.
- Striking results from the Southern California Children's Study indicate that exposure to ozone can cause asthma in children.<sup>31</sup> Children who exercise frequently in smoggy areas are more than three times as likely to develop asthma as those in cleaner parts of the country.

Taken together, these studies paint a picture of profound and irreversible respiratory damage beginning with an infant's first breath of ozone-tainted air, leading to impaired lung development and chronic respiratory disease.

## The Dangers of Pollution from Traffic

Cars and trucks directly emit dangerous pollutants near roadways, in addition to contributing to soot and smog in ambient air. Fuel combustion produces pollutants like nitrogen oxides, small particles, benzene, formaldehyde, and 1,3-butadiene. In sufficient amounts, these pollutants irritate airways and lungs, cause asthma, worsen asthma symptoms, and cause leukemia and other types of cancers.<sup>32</sup>

Exhaust from highways and major roads poses a serious health hazard for anyone who lives, works or goes to school in or near heavy traffic. Scientific studies have shown that automobile exhaust causes serious illnesses and increases the risk of death.

### **Children directly exposed to traffic pollution develop respiratory problems.**

- Researchers in Europe found that children who live or go to school close to busy highways and roads are more likely to suffer from cough, wheezing, and runny nose. Significantly, these children are also more likely to suffer from asthma.<sup>33</sup>
- Researchers in southern California found that children living closer to a highway are more likely to have asthma, more likely to wheeze and more likely to use asthma medication.<sup>34</sup>
- The damage begins at birth: studies have found that infants exposed to traffic-related air pollution during their first year of life are more likely to suffer from coughs, which could later translate into chronic respiratory problems.<sup>35</sup>

### **Air pollution from traffic causes damage that increases the risk of death.**

- People living near highways or highly traveled roads face an increased risk of death from stroke, lung disease and heart disease.<sup>36</sup>

### **Many people assume that being inside a car offers some protection from exhaust—but pollution levels in cars are higher than in the air outdoors, especially in congested traffic.**

- On congested roadways, levels of dangerous pollutants inside vehicles can be up to 10 times higher than in general city air.<sup>37</sup>
- U.S. EPA researchers studied a group of North Carolina highway patrol troopers who regularly work on the road. After breathing elevated levels of particulates while on duty, the troopers' heart rhythms and blood chemistry changed in ways associated with increased risk of heart attack.<sup>38</sup>

In order to improve public health, state leaders must implement policies to reduce pollution directly emitted from vehicles on busy roadways.

# Health Damage Caused by Air Pollution in North Carolina

Health researchers have made significant progress in mapping out the consequences of breathing polluted air, and the results aren't pretty. The most serious impacts include premature death from diseases like cancer and heart disease, respiratory deaths in infants, and new cases of persistent diseases like chronic bronchitis and asthma.

However, these impacts are just the most visible indicators of widespread health damage that affects everyone in the state. Air pollution also causes increased emergency room visits, more frequent asthma attacks, and missed work days due to respiratory illness in otherwise healthy people. At the root of all of these problems, air pollution irreparably damages lung tissues in ways similar to second-hand tobacco smoke.

In this report, we quantify the health impacts of air pollution in North Carolina. Our estimates stem from three basic sources of information:

- The exposure of people to air pollutants,
- Scientific studies documenting how the risk of a relevant health impact changes with increasing air pollution levels, and

- The number of deaths, hospital admissions, and other relevant events in North Carolina in 2003.

Air pollution monitors placed throughout North Carolina by the Department of Environment and Natural Resources help provide the first piece of information. A vast body of scientific literature in which researchers tracked pollution and health effects provides the second piece of information. And the third comes from health statistics maintained by the North Carolina State Center for Health Statistics and the U.S. Agency for Healthcare Research and Quality, estimates by the U.S. Environmental Protection Agency, and additional information from government surveys.

Using this information, we estimate that every year in North Carolina, thousands die prematurely because of soot in the air, thousands are admitted to area hospitals with air-pollution aggravated heart and lung disease, and hundreds of thousands miss work because of air-pollution induced respiratory illness (see Table 1).

Additionally, during the summer smog season, we estimate that smog causes chronic asthma in thousands of North

**Table 1: Public Health Damage from Soot in North Carolina (PM<sub>10</sub>)**

Health Effect	Estimated Cases	Range
Premature Death (Adults)	3,000	2,000 – 4,600
Respiratory Hospital Admissions	2,000	1,700 – 2,600
Cardiovascular Hospital Admissions	2,000	900 – 2,500
New Cases of Chronic Bronchitis	2,500	260 – 4,400
Asthma Attacks	200,000	100,000 – 390,000
Missed Work Days	500,000	440,000 – 520,000
Restricted Activity Days	5 million	4.1 million – 5.5 million
Increased Symptom Days	15 million	7 million – 23 million

**Table 2: Public Health Damage from Smog in North Carolina (Ground-level Ozone<sub>0</sub>)**

Health Effect	Estimated Cases	Range
Adult Onset Asthma (Males, 25+)	1,500	900 – 1,900
Respiratory Hospital Admissions	4,000	3,000 – 5,000
Asthma Attacks	200,000	100,000 – 300,000
Restricted Activity Days	1 million	800,000 – 1.4 million
Increased Symptom Days	4 million	2 million – 6 million

Carolina adults, more than one hundred thousand asthma attacks and millions of days of increased respiratory symptoms like shortness of breath (see Table 2).

## Premature Death

The most serious health impact of exposure to air pollution is premature death. Fine particulates are tied to deaths from respiratory disease, heart disease, lung cancer, and other types of diseases commonly associated with smoking.

## The Evidence

Several decade-long studies have made it quite clear that long-term exposure to pollution shortens lives:

- In 2002, Dr. C. Arden Pope at Brigham Young University and his colleagues published a study tracking more than 500,000 people in 51 metropolitan areas in America for longer than 16 years. He found that when fine particulate levels increased by 10 micrograms per cubic meter, deaths from all causes rose by 4 percent; deaths from cardiopulmonary illness by 6 percent, and deaths from lung cancer by 8 percent.<sup>40</sup> Dr. Pope saw no evidence for a safe level of particulate pollution not tied to increased death rates. Pope estimated that chronic exposure to air pollution in the most polluted cities shortens life expectancy between 1.8 and 3.1 years.<sup>41</sup> He concluded that breathing polluted air like that commonly found

in the Eastern U.S. causes an increased risk of lung cancer similar to that of breathing secondhand smoke.<sup>42</sup>

- Researchers with the World Health Organization in Europe found that air pollution caused 6 percent of all deaths in Switzerland, France and Austria (40,000 per year). Motor vehicle pollution caused about half of these deaths.<sup>43</sup>

Dozens of studies also link short-term exposure to pollution to acute increases in the death rate:

- In a study of heart attack patients in Boston, Dr. Annette Peters and her colleagues at the Harvard University School of Public Health found that as pollution levels rose, so did the frequency of heart attacks a few hours to a day later.<sup>44</sup> An increase in fine particles of 25 micrograms per cubic meter resulted in a 69 percent increase in the relative risk of having a heart attack over the following day.
- Dr. Jonathan Samet from Johns Hopkins University's Bloomberg School of Public Health and his

## How We Estimated the Health Effects of Air Pollution

In the 1990 amendments to the Clean Air Act, Congress required the EPA to report on the benefits and costs of Clean Air Act regulations. In November 1999, the EPA released a report outlining the health and economic impact of clean air efforts. In addition, scientists with the World Health Organization produced a report in 2000 estimating the public health impact of particulate air pollution from motor vehicles.<sup>39</sup>

Environment North Carolina Research & Policy Center adapted the methodology developed by these experts to estimate the health effects of air pollution in North Carolina.

First, we gathered statistics on how many deaths, hospital admissions and other relevant events happened in the state in 2003. Next, we estimated how much air pollution (above natural background levels) people are exposed to by looking at data from soot and smog monitors placed throughout the state. Finally, we obtained estimates of how much the risk of health problems increases with exposure to a specific amount of air pollution. Combining these three pieces of information allowed us to estimate what fraction of deaths and other relevant health problems could be attributed to air pollution.

We report the effects of air pollution including a range of values to emphasize that the estimates have an inherent level of uncertainty. Reported ranges represent the 95 percent confidence interval derived by scientists for the relationship between air pollution and the frequency of health outcomes, or where the estimate would be expected to lie 95 times out of 100 observations. The range of values presented here is our best estimate of the public health toll of air pollution in North Carolina. For more specific details on how the estimates were made and a discussion of factors that could make the actual impacts higher or lower, see the Methodology section.

colleagues studied health and air pollution data from 90 cities in the U.S. and found a link between daily pollution levels and daily death rates from chronic heart and lung disease. The link was strongest in the Northeast, the industrial Midwest, and in Southern California.<sup>45</sup>

- Dr. Kazuhiko Ito and his colleagues at New York University found that increases in ozone levels lead to a higher risk of death. As daily 1-hour maximum ozone concentrations in seven U.S. cities rose by 10 parts per billion, risk of death rose by 0.4 percent.<sup>46</sup>

Pollution associated with burning fossil fuels is specifically tied to increased mortality, as opposed to particles from dust-storms and other natural events.<sup>47</sup> Other studies show that these effects are not merely accelerating the death of elderly and infirm adults already on the brink of death, but also kill some infants and adults who otherwise would have many years of health remaining.<sup>48</sup>

### North Carolina Estimate

We estimate that soot pollution causes about 3,000 deaths each year, or 3 to 7 percent of all deaths not caused by injuries or accidents. This estimate is comparable to the World Health Organization study of air pollution impacts, which reported that 6 percent of all mortality in Switzerland, France and Austria is linked to air pollution.<sup>49</sup>

This finding ranks air pollution as the third leading cause of mortality in North Carolina, behind smoking and poor diet/physical inactivity. In 2004, researchers published estimates for the leading causes of death in the U.S. as a whole.<sup>50</sup> According to these estimates, smoking causes 18 percent of all deaths, poor diet and physical inactivity causes 15.2 percent of all deaths and alcohol consumption leads to 3.5 percent of all deaths. Air pollution in

North Carolina—causing roughly 4.5 percent of all deaths—ranks just above alcohol consumption as a risk factor in premature mortality.

**Table 3: Yearly Premature Deaths Caused by Air Pollution in North Carolina**

Health Effect	Estimated Cases	Range
Premature Death (Adults)	3,000	2,000 – 4,600

## Hospital Stays and Emergency Room Visits

As levels of air pollution increase, so do the number of people admitted into hospital wards or emergency departments suffering from severe respiratory and cardiovascular disease.

### The Evidence

- Dr. Jonathan Samet from Johns Hopkins University's Bloomberg School of Public Health and his colleagues found that increases in daily pollution levels were linked to increased hospital admissions for cardiovascular disease, pneumonia, and chronic obstructive pulmonary disorder.<sup>57</sup>
- Dr. Joel Schwartz of Harvard University and his colleagues documented links between ozone and hospitalization rates for cardiovascular and respiratory disease in Birmingham, Detroit, Minneapolis-St. Paul, and Tucson.<sup>58</sup> An increase of soot levels by 100 micrograms per cubic meter and ozone by 50 parts per billion increased the risk of hospitalization for chronic

## Global Warming and Public Health

Soot and smog are not the only pollutants in North Carolina's air. Global warming pollution also has serious consequences for the health and well being of all North Carolinians.

Scientists project that global warming could raise average temperatures in North Carolina by 1° F to 5° F over the next century.<sup>51</sup> Coupled with a projected increase in precipitation, the heat index in the Southeast could climb by 8 to 15° F.<sup>52</sup> Among a host of negative impacts—from coastal flooding to ecosystem disruption—such a temperature increase would increase air pollution and harm public health.<sup>53</sup>

Scientific evidence shows that as temperatures grow hotter in the summer, so does the risk of death. For example, scientists tracking hospitalization of patients for cardiovascular diseases in Denver in the summer months of 1993 to 1997 found that higher temperatures increased the number of elderly people suffering from heart attacks and congestive heart failure.<sup>54</sup> In the summer of 2005 a severe heat wave passed through France, killing an estimated 15,000 people.<sup>55</sup>

The U.S. Environmental Protection Agency estimates that an increase of 3° F in the average summer temperature in a city like Greensboro would cause heat-related deaths to increase by nearly 70 percent.<sup>56</sup>

respiratory disease in the range of 20 percent to 100 percent.

- Dr. George Thurston at the New York University School of Medicine and Dr. Richard Burnett at Environment Canada have repeatedly linked respiratory and cardiovascular hospital admissions with the levels of summertime haze air pollution.<sup>59</sup> According to these studies, summertime haze pollution was responsible for 24 percent of respiratory hospital admissions in Toronto, and up to half of admissions on particularly bad air days.
- Dr. Paul Liroy and his colleagues at the Rutgers Environmental and Occupational Health Sciences Institute and UMDNJ—Robert Wood Johnson Medical School saw increases in the number of asthma emergency room visits in central and northern New Jersey on high-smog summer days.<sup>60</sup> Emergency room visits occurred 28 percent more frequently when the average ozone levels were greater than 60 ppb than when they were lower than this level. This study demonstrates health effects of ozone exposure at levels well below the EPA health standard of 80 ppb over an 8 hour period.
- Dr. Joel Schwartz from Harvard University and his colleagues at the U.S. EPA found that as fine soot levels increased in the Seattle area, so did emergency room visits for asthma.<sup>61</sup> An increase in fine soot levels of 30 micrograms per cubic meter increased the relative risk of needing emergency medical attention for asthma by 12 percent. The daily fine soot levels never exceeded 70 percent of the EPA health standard at the time.
- Dr. Jennifer Peel and her colleagues at Emory University looked at air pollution levels and emergency room visits at 31 hospitals in Atlanta from 1993 to 2000—a statistically powerful

sample comprised of more than 4 million patients. She found that increased levels of soot and smog pollution led to increased emergency room visits for upper respiratory infections, pneumonia and other respiratory conditions.<sup>62</sup>

### North Carolina Estimate

We estimate that soot pollution causes 2,000 respiratory and 2,000 cardiovascular hospital admissions each year, and smog causes 4,000 respiratory hospital admissions during the summer smog season. This represents between 5 and 8 percent of respiratory hospital admissions in 2003, and between 0.5 and 1.5 percent of cardiovascular hospital admissions.

## New Cases of Chronic Disease—Asthma and Bronchitis

Air pollution can cause chronic diseases in addition to triggering short-term health damage. From new cases of chronic asthma in otherwise healthy children and adults to

the development of chronic bronchitis in elderly people, these are severe diseases that cause significant distress for hundreds of thousands of North Carolina residents.

### The Evidence

- Dr. Rob McConnell at the University of Southern California School of Medicine and his colleagues found that children who exercise a lot develop asthma at higher rates in more polluted areas. The researchers followed for five years more than 3,500 children from the fourth, seventh, and tenth grades with no history of asthma. During that time, 265 became asthmatic. Children who played three or more sports in communities with high smog levels developed asthma at over three times the rate of children in low-smog communities. Children who spent relatively high amounts of time outdoors were 1.4 times more likely to get asthma in polluted areas compared to cleaner ones.<sup>63</sup> The levels of air pollution in all of the communities examined were well below the U.S. EPA health standard of 80 ppb over an eight hour period.

**Table 4: Annual Hospital Admissions Caused by Air Pollution in North Carolina**

Health Effect	Estimated Cases	Range
Respiratory Hospital Admissions (Soot)	2,000	1,700 – 2,600
Cardiovascular Hospital Admissions (Soot)	2,000	900 – 2,500
Respiratory Hospital Admissions (Ozone)	4,000	3,000 – 5,000

**Table 5: New Cases of Chronic Respiratory Disease Caused by Air Pollution in North Carolina Annually**

Health Effect	Estimated Cases	Range
New Cases of Chronic Bronchitis (Soot)	2,500	260 – 4,400
Adult Onset Asthma (Males, 25+)	1,500	900 – 1,900

- In a follow up study, Dr. McConnell and his colleagues found that children living closer to a major highway were more likely to have asthma, pointing to traffic-related pollution as a likely cause of asthma.<sup>64</sup>
- Dr. William McDonnell at the U.S. EPA National Health and Environmental Effects Research Laboratory and his colleagues found a connection between long-term exposure to smog and development of asthma in adults. The researchers followed more than 3,000 non-smoking adults for 15 years in California. During this period, just over 3 percent of the men and just over 4 percent of the women reported a diagnosis of asthma. Several factors increased the risk of developing asthma, including: history of exposure to tobacco smoke, childhood pneumonia or bronchitis; and exposure to ozone in men.<sup>65</sup>
- In Taiwan, researchers linked development of asthma with several individual air pollutants: fine soot, sulfur dioxide, nitrogen dioxide, and carbon monoxide. The scientists surveyed more than 160,000 schoolchildren and looked at levels of air pollutants, finding that air pollution increased asthma prevalence by as much as 29 percent, independent of exposure to second-hand tobacco smoke.<sup>66</sup> Similar research in Hong Kong showed that children living in areas with higher air pollution had higher levels of asthma and less healthy lungs.<sup>67</sup>
- Dr. Joel Schwartz and others identified links between particulate levels and physician diagnoses of chronic bronchitis by looking at health records and air pollution levels in 53 U.S. metropolitan areas.<sup>68</sup> For every 10 microgram per cubic meter increase in total particulates, the relative risk for chronic bronchitis rose about 7 percent.

Asthma prevalence is increasing in the U.S. and worldwide, for unknown reasons. In the U.S., the Centers for Disease Control and Prevention (CDC) estimates that prevalence among persons up to 17 years old increased about 5 percent per year from 1980 to 1995.<sup>69</sup> Deaths due to asthma have doubled, and now amount to 5,000 per year.<sup>70</sup> The trend in the number of children with active asthma in North Carolina also has been increasing over the past few decades, to the point where just under one in 10 children are affected.<sup>71</sup> According to a survey carried out by the CDC in 2003, 7.1 percent of North Carolina adults have been diagnosed with asthma.<sup>72</sup>

### North Carolina Estimate

We estimate that air pollution causes 2,500 new cases of chronic bronchitis and 1,500 cases of adult onset asthma among North Carolina residents every year.<sup>73</sup> The contribution of air pollution may be much higher when pediatric asthma is considered.<sup>74</sup>

## Asthma Attacks

When pollution levels rise, so do the frequency of asthma attacks suffered by asthmatic children and adults.

### The Evidence

- Dr. George Thurston and his colleagues at the New York University School of Medicine documented increased asthma attacks, respiratory difficulty, and reduced lung function in children on high pollution days.<sup>75</sup> The researchers tracked children attending the American Lung Association's Connecticut "Asthma Camp" during summer months. On the highest pollution days, the risk of asthma attacks requiring medication and chest tightness climbed 40 percent higher than usual.

**Table 6: Annual Asthma Attacks Triggered by Air Pollution in North Carolina**

Health Effect	Estimated Cases	Range
Asthma Attacks (Soot)	200,000	100,000 – 390,000
Asthma Attacks (Ozone)	200,000	100,000 – 300,000

- In the mid 1970s, the Environmental Protection Agency collected asthma attack diaries from Los Angeles residents. Asthma attacks were reported more frequently when smog and soot levels were high, as well as when the weather was cool.<sup>76</sup>

### North Carolina Estimate

We estimate that soot pollution causes 200,000 asthma attacks and smog pollution causes another 200,000 asthma attacks among North Carolina asthmatics every year.

### Missed Work Days and Sick Days

Air pollution can also affect the health of people with no chronic respiratory illness. On high pollution days, the number of people feeling ill with symptoms like shortness of breath, runny or stuffy noses, coughs, burning eyes, wheezing, and chest pain increases dramatically. These symptoms can cause people to miss work or school, or force them to limit their usual activity levels.

### The Evidence

- Dr. Bart Ostro at the California EPA linked high air pollution levels with missed work days and illness days reported in the Health Interview Survey collected yearly by the U.S. Centers for Disease Control and Prevention.<sup>77</sup>
- Dr. Joel Schwartz of Harvard and his colleagues found that elementary school children in six U.S. cities suffered from coughs and other lower respiratory symptoms more often on days when soot and smog levels were high.<sup>78</sup>

### North Carolina Estimate

We estimate that soot pollution causes 500,000 missed work days, 5 million person-days when illness limits normal activity levels, and 15 million person-days with the presence of respiratory symptoms such as shortness of breath, runny or stuffy noses, coughs, burning eyes, wheezing, or chest pain. In addition, we estimate that smog causes 1 million person-days when air pollution limits normal activity and 4 million person-days with respiratory symptoms.

**Table 7: Annual Missed Work Days and Increased Respiratory Symptom Days Caused by Air Pollution in North Carolina**

Health Effect	Estimated Cases	Range
Missed Work Days (Soot)	500,000	440,000 – 520,000
Restricted Activity Days (Soot)	5 million	4.1 million – 5.5 million
Increased Symptom Days (Soot)	15 million	7 million – 23 million
Restricted Activity Days (Smog)	1 million	800,000 – 1.4 million
Increased Symptom Days (Smog)	4 million	2 million – 6 million

# Air Pollution and North Carolina's Children

Children are especially vulnerable to the effects of air pollution.<sup>79</sup> First, children are developing into adults. Their lungs are growing. Injuries sustained during this time can cause permanent damage that will have life-long effects. Second, children breathe more air per pound of body weight and thus inhale larger doses of pollutants than adults.

Children in North Carolina are constantly exposed to air pollution, breathing it day in and day out. Recent science has shown that this exposure causes a range of lung injuries, even among otherwise healthy infants and children. Children exposed to air pollution can't breathe as well as children growing up in cleaner areas. Their lungs are scarred and less flexible than they should be, their lungs hold less

air, and they aren't as able to breathe normally. These injuries manifest themselves in respiratory illness, missed school days, increased doctor visits, hospitalizations, and for a small group, death.<sup>80</sup>

Environment North Carolina Research & Policy Center compiled air pollution data, scientific reports about how air pollution levels affect children's health, and baseline health statistics maintained by the state Center for Health Statistics and the EPA. We used this information to estimate the health impacts of pollution on children in North Carolina. (For more details, see the Methodology section.)

We estimate that air pollution kills several dozen infants a year and causes more than one thousand emergency room visits for childhood asthma, tens of thousands of

**Table 8: Air Pollution Damage to Children's Health in North Carolina**

Health Effect	Estimated Cases	Range
Infant Deaths	50	30 – 60
Asthma ER Visits	1,500	200 – 3,500
Acute Bronchitis	20,000	13,000 – 33,000
Asthma Attacks	100,000	90,000 – 120,000
Missed School Days	300,000	NA

**Table 9: Yearly Infant Deaths from Air Pollution in North Carolina**

Health Effect	Estimated Cases	Range
Infant Deaths	50	30 – 60

cases of acute bronchitis, close to one hundred thousand asthma attacks and hundreds of thousands of missed school days. (See Table 8.)

## Infant Death

Air pollution not only kills elderly and sick people. It also causes premature death in infants and young children. Experiments have tied particulate levels to deaths from both respiratory disease and sudden infant death syndrome.

### The Evidence

- Dr. Tracey Woodruff at the U.S. EPA and her colleagues linked fine soot pollution levels and neonatal deaths in 86 U.S. metropolitan areas.<sup>81</sup> Normal-weight infants less than one year old born in high soot areas were 40 percent more likely to die of respiratory disease, and 26 percent more likely to die from sudden infant death syndrome than infants born in low soot areas.
- Researchers in the Czech Republic found that newborn deaths due to respiratory causes were linked to increased levels of fine soot, sulfur dioxide, and oxides of nitrogen.<sup>82</sup> The study concluded, “the effects of air pollution on infant mortality are specific for respiratory causes in [the period between one month and one year of age], are independent of socioeconomic factors, and are not mediated by birth weight or gestational age.”

- The National Bureau of Economic Research found that as levels of particles fell during a recession in the early 1980s, so did rates of death in newborn children younger than 28 days old. Specifically in Pennsylvania, researchers found that when total fine particulate levels dropped 25 percent, newborn death rates from cardiopulmonary and respiratory causes fell 14 percent.<sup>83</sup>

### North Carolina Estimate

We estimate that soot pollution causes 50 infant deaths in North Carolina each year, or 4 to 7 percent of all infant deaths.

## Hospitalization and Emergency Room Trips

As air pollution levels rise, children end up in the emergency room with respiratory problems at higher rates. Some of them require hospitalization for longer-term care.

### The Evidence

- Dr. Michael Friedman of the U.S. Centers for Disease Control and Prevention and his colleagues found that reduced traffic levels and higher public transit use during the 1996 Summer Olympics in Atlanta significantly reduced smog levels and also emergency room visits for childhood asthma.<sup>84</sup> One-hour peak ozone levels decreased by 27 percent, while the number of children visiting the

## Reducing Air Pollution Protects Children’s Health: The Case of the 1996 Olympics in Atlanta

The 1996 Summer Olympic Games in Atlanta offered researchers a unique opportunity to observe the connection between lowered pollution levels and improved health.<sup>85</sup>

Atlanta implemented a comprehensive transit plan as a part of the Olympic Games. The plan was designed to reduce congestion in the downtown area and reduce travel delays. Atlanta launched an expanded 24-hour-a-day public transportation network, added 1,000 buses for park-and-ride service, encouraged local employers to institute alternative work hours and telecommuting, and closed the downtown area to private vehicles.

The transit plan produced impressive results, despite the million or so additional visitors to the city. Weekday morning traffic trips declined by 22.7 percent and public transportation ridership increased by 217 percent.

The plan produced some unintended benefits for air quality and health that were equally impressive. The average daily maximum ozone levels decreased by 28 percent, from 81 ppb before and after the Olympics to 59 ppb during the Olympics. Presumably, this effect resulted from the decreased levels of traffic-related air pollution building up in the morning rush hour. Nearby cities did not experience similar reductions in ozone pollution.

At the same time, asthma-related emergency room visits for children decreased by 41.6 percent in a Medicaid database, 44.1 percent in an HMO database, and 11.1 percent in two major pediatric emergency departments. Additionally, hospitalizations for asthma decreased by 19.1 percent. Unfortunately, Atlanta discontinued the transit program at the conclusion of the Olympics, and pollution levels and emergency room visit rates returned to normal.

This experience powerfully demonstrates how reducing pollution levels would benefit the health of children. It also highlights the role that motor vehicles play in creating high levels of urban pollution and how better public transit can quickly reduce air pollution levels.

Dr. Michael Friedman of the U.S. Centers for Disease Control and Prevention, one of the authors of the study, said that the results “provide evidence that decreasing automobile use can reduce the burden of asthma in our cities and that citywide efforts to reduce rush-hour automobile traffic through the use of public transportation and altered work schedules is possible in America.”<sup>86</sup>

emergency room for asthma fell 41.6 percent in a Medicaid database, 44.1 percent in an HMO database, and 11.1 percent in two major pediatric emergency departments. In other words, every 10 ppb decrease in smog levels reduced the relative risk of children needing emergency medical

attention for asthma by roughly 8 percent.

### North Carolina Estimate

We estimate that air pollution causes 1,500 asthma emergency room visits among North Carolina children each year.

**Table 10: Yearly Pediatric Respiratory ER Visits Caused by Air Pollution in North Carolina**

Health Effect	Estimated Cases	Range
Asthma ER Visits	1,500	200 – 3,500

## Asthma Attacks, Acute Bronchitis and Missed School Days

Air pollution triggers asthma attacks and increases cases of acute bronchitis in children. Asthma is the leading chronic illness in children and the number one cause of missed school days in the United States.<sup>87</sup> The Centers for Disease Control and Prevention estimates that asthma prevalence among persons up to 17 years old increased about 5 percent per year from 1980 to 1995.<sup>88</sup> Air pollution worsens the impact of this disease, causes other acute respiratory illnesses, and increases school absence rates.

### The Evidence

- Dr. Janneane Gent at the Yale University School of Medicine and her colleagues recently published a study showing that children with asthma are vulnerable to air pollution well below EPA health standards.<sup>89</sup> According to the study, every 50 ppb ozone increase yields a 35 percent increased likelihood of wheezing, and a 47 percent increased likelihood of chest tightness. A follow-up study showed that infants, particularly those with asthmatic mothers, suffer from increased

wheezing and difficulty breathing on days with high ozone levels.<sup>90</sup>

- Dr. Douglas Dockery at Harvard University and his colleagues showed that children living in areas with high levels of acidic particle pollution were 66 percent more likely to have had an episode of bronchitis in the last year than children in low pollution areas.<sup>91</sup>
- Researchers participating in the Southern California Children’s Health Study found that increased smog pollution causes more children to stay home from school.<sup>92</sup> When ozone levels rose by 20 ppb, illness-related absence rates went up by 63 percent, and by 174 percent for lower respiratory illnesses with wet cough.
- Researchers in Korea found the same relationship between air pollution and school absences.<sup>93</sup> When air pollution levels rose, so did illness-related absences. When pollution levels fell, more children came in to school.

### North Carolina Estimate

We estimate that air pollution causes 20,000 cases of acute bronchitis and 100,000 asthma attacks among North Carolina children each year. Additionally, air pollution causes in the range of 300,000 missed school days each year.

**Table 11: Asthma Attacks and Acute Bronchitis Caused by Air Pollution in N.C**

Health Effect	Estimated Cases	Range
Acute Bronchitis	20,000	13,000 – 33,000
Asthma Attacks	100,000	90,000 – 120,000
Missed School Days	300,000	NA

# Clean Air Policy Recommendations

Solutions to North Carolina's air quality problems are readily available. Strategies already in widespread use—from modern emission controls for cars and power plants to efficient transit systems—can cut air pollution and help people to live healthy lives.

Aggressive action will be required on both the state and regional level to reduce air pollution and reduce the costs society pays for the use of polluting fuels. In order to have the greatest impact, action should focus first on the largest sources of pollution.

## Sources of Dirty Air

In North Carolina, mobile sources like cars, trucks, buses, and off-road equipment are the largest source of air pollution—especially in urban areas. Additional pollutants come from power plants, industrial facilities, and chemical use. Pollution sources in neighboring states are also a significant part of the problem.

Within the state in 1999, almost half of smog-forming emissions (oxides of nitrogen and volatile organic compounds) came from on-road and off-road mobile sources

like cars, trucks, and construction equipment. (See Table 12.) Mobile sources directly released just under half of all particulate matter under 10 micrometers in diameter. Traffic is an area of particular importance, since pollutants are emitted at ground level and in close proximity to areas where people live.

In 1999, electricity generation was responsible for 80 percent of the state's releases of sulfur dioxide—one of the precursors of soot particles. In 2002, North Carolina passed the Clean Smokestacks Act, a law that will significantly reduce emissions from coal-fired power plants within the state over the next decade. Nitrogen oxide emissions from power plants will drop 77 percent by 2009 and sulfur dioxide emissions will drop 73 percent by 2013.<sup>24</sup>

With the passage of this law, mobile sources are now the highest priority for reducing pollution in North Carolina.

## Policies Aimed at the Largest Pollution Sources

An effective suite of policies aimed at

reducing air pollution in North Carolina would include the following:

**State Level Actions:**

- *Strengthen auto emission standards in line with New York, Massachusetts, New Jersey, Connecticut, Rhode Island, Maine, Vermont, California, Oregon and Washington.* In these states, auto-makers are required to manufacture and sell vehicles that emit less pollution and incorporate advanced technologies.
- *Require diesel engines to be retrofitted with particulate filtration systems and low-sulfur fuel.* Diesel engines are a significant source of fine particles. New federal diesel standards will be phased in starting in 2007, reducing emissions from new highway and off-road vehicles. North Carolina can reduce emissions from older vehicles by retrofitting their emission control systems for lower pollution. State-owned vehicle fleets such as school buses and road construction equipment should be included, as well as off-road diesel vehicles like bulldozers.
- *Reduce car-dependent land use practices and sprawl.* North Carolina should ensure that future growth, development, and redevelopment focuses on creating livable, transit-oriented communities to reverse the trend of yearly increases in vehicle miles traveled that lead to greater pollution.

North Carolina should also increase the proportion of transportation funding for clean public transit to provide residents with alternatives to driving.

**Federal and Regional Level Actions:**

- *Fully enforce the Clean Smokestacks Act, pursuing all available means to reduce pollution in neighboring states.* The Clean Smokestacks Act instructs the North Carolina attorney general to use all legal means to force pollution sources in neighboring states to clean up. The state should continue to push for strong pollution controls on Tennessee Valley Authority power plants in upwind states.
- *Advocate adoption of these state policies among neighboring and upwind states.* Reducing air pollution emissions in North Carolina will have benefits for neighboring states. North Carolina should encourage other states, especially those upwind from the state, to adopt similar air pollution control policies. Ultimately, regional cooperation will be required to reduce overall air pollution levels.
- *Restore the New Source Review provision of the Clean Air Act and require the oldest coal-fired power plants and other industrial facilities in the country to install modern emissions control technology.* The EPA recently enacted regulations

**Table 12. Emissions of Selected Air Pollutants in 1999 by Source<sup>95</sup>**

	Total (Tons)	Mobile Sources	Area Sources	Point Sources
Oxides of Nitrogen	674,848	55%	5%	40%
Volatile Organic Compounds	635,687	39%	50%	11%
PM <sub>10</sub>	390,632	44%	49%	7%
Sulfur Dioxide	607,743	5%	5%	90%

relieving power plants and industrial facilities grandfathered under the original Clean Air Act of responsibility to upgrade their emissions controls when upgrading their facilities. This change limits the effectiveness of the Clean Air Act and effectively subsidizes a few industries at the expense of public health. It should be reversed as soon as possible.

- *Limit nationwide industrial emissions of sulfur dioxide, nitrogen oxides, and mercury to between 10 percent and 30 percent of 2000 levels.* Placing a national cap on point-source emissions of air pollutants could dramatically reduce

the levels of pollution plaguing the eastern seaboard of the U.S., and contribute to a regional solution to the air pollution problem.

- *Strengthen national emission standards for cars, trucks, and off-road vehicles.* The EPA sets national emission standards for cars, trucks, and off-road vehicles. However, California has designed a more effective and ambitious mobile-source emissions control program that includes requirement for manufacturers to produce cleaner vehicles with modern technologies. The EPA should update its standards to match or exceed the California program.

# Methodology

To quantify the health impacts of air pollution, we relied on three basic pieces of information:

- The exposure of people to air pollutants,
- How the risk of a given health impact changes with increasing air pollution levels, and
- The number of deaths, hospital admissions, and other relevant events in North Carolina in 2003.

Air pollution monitors placed throughout the state by the North Carolina Department of Environment and Natural Resources helped provide the first piece of information. A vast body of scientific literature in which researchers tracked pollution and health effects provided the second piece of information. And the third came primarily from health statistics maintained by the state Department of Health and Senior Services, plus additional information from estimates and surveys by governmental agencies and in the scientific literature.

We compiled this information to estimate the health impacts of pollution in

North Carolina, adapting methodology used by the U.S. EPA in a study on the benefits and costs of the Clean Air Act and the World Health Organization in a study on the health impact of vehicle pollution in Europe.<sup>96</sup> The sections below outline the sources of this information and how we used it to derive our results.

## Air Pollution Exposure

We obtained annual mean levels of pollution from the U.S. EPA *AIRData* online database of air pollution monitoring data for the year 2003.<sup>97</sup> We obtained the average daily one-hour peak ozone levels reported during the summer smog season from April through October and annual mean particulate levels for particulates less than 2.5 micrometers in diameter ( $PM_{2.5}$ ).

We translated  $PM_{2.5}$  data into  $PM_{10}$  data, because many of the scientific studies linking air pollution and health effects were carried out in terms of  $PM_{10}$ , and the relative risk figures obtained from the World Health Organization were listed in terms of  $PM_{10}$ .<sup>98</sup> Because  $PM_{2.5}$  is a subset of  $PM_{10}$ , their concentrations are related. In accordance with assumptions made by the World Health Organization, we assumed

that  $PM_{2.5}$  levels were 60 percent of  $PM_{10}$  levels.<sup>99</sup>

We interpolated air pollution data from a nine-state region (including South Carolina, Georgia, Tennessee, Kentucky, West Virginia, Virginia, Maryland, Delaware and North Carolina) to estimate annual mean pollution levels across North Carolina. (ArcView 9.1 Spatial Analyst software, spline interpolation, 75 to 100 monitor points used in each iteration, 0.5 weighting factor, regularized output.) The results of this interpolation are graphically shown in Figures 2 and 3 on page 10.

Using the zonal statistics function of ArcView 9.1 software, we mapped air pollution levels to the census tract level in North Carolina. Coupled with population figures from the 2000 census, we derived population-weighted annual average exposure estimates for residents of each county in the state. We used 2003 exposure levels as representative of current conditions, and do not take into account pollution levels from earlier years or forecasts of pollution levels in the future.

We define the impact of air pollution as the change in the number of various health outcomes if air pollution exposure were reduced to natural background levels in the absence of anthropogenic emissions from North America, but with continuing emissions from the rest of the world. For ozone, we used a background level of 20 ppb, in accordance with modeling from Harvard showing the natural background between 15 and 30 ppb, with lower levels during the season when overall ozone levels are highest.<sup>100</sup> For particulate matter ( $PM_{10}$ ), we estimated a background level of 7.5 micrograms per cubic meter, in accordance with the World Health Organization.<sup>101</sup>

### **Baseline Frequency of Health Problems in North Carolina**

We obtained the baseline frequency of health outcomes in North Carolina in 2003 from statistics maintained by the North Carolina State Center for Health Statistics

and the U.S. Agency for Healthcare Research and Quality, or, when more specific information was unavailable, published estimates for the American population as a whole from the U.S. EPA. Table 13 lists the relevant health outcomes and data sources.

Where specific data was not available, we assumed that 50 percent of all health effects that could be affected by ground-level ozone happened during the April through October ozone monitoring season, and only considered the effects of ozone on that period of time.

We obtained North Carolina county population figures by age group from the North Carolina State Demographics department to translate the relevant rates in Table 13 to baseline population frequencies for the state.<sup>102</sup>

### **The Relationship Between Exposure and Frequency of Health Effects**

A vast body of scientific literature in which researchers tracked pollution and health effects provides information about how the frequency of health effects changes with changing exposure to air pollution. These studies are known as epidemiological studies. Most epidemiological studies report the exposure-response relationship for air pollution exposure as a relative risk (RR). If the relative risk equals 1, then the pollutant in question does not influence the health outcome. If the relative risk exceeds one, then the pollutant and the health outcome are linked. Most studies report a considerable range in which the relative risk actually lies, because of sources of statistical uncertainty. This range is called the 95 percent confidence interval. We use the upper and lower bounds of these intervals to derive the ranges for each health effect we report.

Following assumptions made by the World Health Organization in calculating the impact of traffic-related air pollution:<sup>117</sup>

**Table 13: Baseline Frequencies of Health Problems in North Carolina**

Health Outcome	Baseline Frequency in North Carolina
Mortality (Deaths per person per year), excluding violence or accidental deaths. <sup>103</sup>	2003 data obtained by county of residence and by age group from the NC State Center for Health Statistics.
Infant mortality <sup>104</sup>	2003 data obtained by county of residence and by age group from the NC State Center for Health Statistics.
Respiratory hospital admissions (ICD 390-459) <sup>105</sup>	Data obtained by county of residence from the North Carolina State Inpatient Database.
Cardiovascular hospital admissions (ICD 460-519) <sup>106</sup>	Data obtained by county of residence from the North Carolina State Inpatient Database.
Annual chronic bronchitis incidence per person <sup>107</sup>	0.0038
Annual chronic asthma incidence among adults 27 years of age and older in ozone season. <sup>108</sup>	0.0011
Asthma prevalence among adults in NC <sup>109</sup>	7.1 percent (Range of 6.3-7.9)
Asthma attacks per asthmatic per year <sup>110</sup>	9.86
Asthma ER visits per year among all children 0-15 years of age <sup>111</sup>	0.01
Asthma ER visits per year among adults. <sup>112</sup>	0.0071
Number of children per year who get acute bronchitis <sup>113</sup>	4.4 percent
Yearly missed work days per worker (adults between the ages of 18 and 65) <sup>114</sup>	2.4
School absences per student per year due to illness <sup>115</sup>	6
Restricted activity days per person per year <sup>116</sup>	6.46

- Our impact assessment includes both short-term and long-term impacts of air pollution.
- Estimates for deaths and incidence of asthma and chronic bronchitis are based on the long-term effect of air pollution. (For example, for mortality we used studies that tracked large groups of people over many years (cohort studies), comparing mortality with air pollution exposure. These studies indirectly capture the effects of chronic problems like cancer and heart disease that would not be completely revealed by short-term or time-series studies.)
- For hospital admissions, asthma attacks, acute bronchitis, restricted activity days and respiratory symptom days, we applied short-term effect estimates from studies that looked at daily variations of air pollution and

**Equation 1:**<sup>118</sup>

**Air Pollution Attributable Portion** =  $[y_o / ( 1 + ((RR - 1) \times \Delta P) ) ] \times Pop \times RR \times \Delta P$   
 Where:  
 $y_o$  = Frequency of health effect;  
 $RR$  = Relative Risk associated with increased exposure of 1 [unit];  
 Pop = Relevant Population; and  
 $\Delta P$  = Exposure of relevant population to pollution above natural background levels.

changes in the frequency of the relevant health outcome.

- We used annual average mean levels of air pollution to estimate exposure levels for both short- and long-term effects. In other words, we assume that the annual impact of the pollutant corresponds to the sum of all the daily effects across one year.

Calculating the impact of air pollution on a given health outcome generally follows Equation 1.

All of the estimates for particulate matter relevant to children and adults followed this pattern, as described by the World Health Organization.<sup>119</sup>

The remaining estimates related to ozone relied on concentration-response functions developed by the U.S. EPA for its study on the benefits and costs of the Clean Air Act, as listed in table 14.<sup>120</sup> In the table,  $y_o$  represents the frequency of the health effect, EXP is the exponential function with base  $e$ ,  $\Delta O_3$  represents the exposure of the relevant population to

ozone pollution above natural background levels during ozone season,  $\beta$  represents the coefficient derived by EPA from epidemiological literature as listed in Table 16, and Pop is the relevant population.

**Particulates**

Table 15 lists the relative risk numbers for an increase in particulate matter pollution of one microgram per cubic meter derived from epidemiology experiments, the 95 percent confidence interval, and the citation for the original experiment.

**Ozone**

Table 16 lists the relative risk for an increase in ground-level ozone pollution of 1 part per billion, derived from epidemiology studies. It also lists confidence limits and the citation for the original study.

For studies that used ozone measurements other than the daily one hour peak concentration, we converted North Carolina exposure data to the appropriate

**Table 14: Concentration-Response Functions for Ozone Exposure**<sup>121</sup>

Health Effect	Concentration—Response Function
Adult Onset Asthma	$-[y_o / ((1 - y_o)(EXP(\Delta O_3 * \beta)) + y_o) - y_o] * Pop$
Respiratory Hospital Admissions	$-[y_o * (EXP(-\Delta O_3 * \beta) - 1)] * Pop$
Asthma Attacks	$-[y_o / ((1 - y_o)(EXP(\Delta O_3 * \beta)) + y_o) - y_o] * Pop$
Restricted Activity Days	$-[y_o * (EXP(-\Delta O_3 * \beta) - 1)] * Pop$
Increased Symptom Days	$\beta * \Delta O_3 * Pop$

**Table 15: Relative Risk Figures Derived from the Scientific Literature, PM<sub>10</sub>**

Health Effect	Population	Relative Risk of Effect	Lower Confidence Limit	Upper Confidence Limit	Reference
Premature Death	Age 30 +	1.0043	1.0026	1.0061	122
Respiratory Hospital Admissions	All Ages	1.0017	1.0013	1.0020	123
Cardiovascular Hospital Admissions	All Ages	1.0008	1.0004	1.0011	124
Asthma Attacks	Asthmatics	1.0039	1.0019	1.0059	125
Chronic Bronchitis	Age 25 +	1.0098	1.0009	1.0194	126
Work Loss Days	Age 18-65	1.0046	1.0042	1.0050	127
Restricted Activity Days	Age 20 +	1.0094	1.0079	1.0109	128
Increased Symptom Days	Age 18 +	1.17	1.08	1.26	129

measure using the following estimated conversion factors: 12-hour ozone levels are 50 percent of the daily one-hour maximum, 8-hour ozone levels are 70 percent of the daily one-hour maximum, and 5-hour ozone levels are 85 percent of the daily one-hour maximum.

**Children, PM<sub>10</sub>**

Table 17 lists the relative risk numbers for children associated with an increase in particulate matter pollution of 1 microgram per cubic meter or ozone of 1 part per billion. The table also lists confidence limits and the citation for the original study.

**Sources of Uncertainty**

As discussed in this report, scientific evidence clearly shows that air pollution causes significant damage to the health of the public across the state and the country. However, the extent and scale of the damage are subject to remaining scientific uncertainties and gaps in knowledge. Possible sources of uncertainty include, but are not limited to:

- This report does not capture all the possible effects of air pollution. For example, air pollution could have effects on development in the womb or early in life that predispose adults to disease later in life. Further study

**Table 16: Relative Risk Figures and Coefficients Derived from the Scientific Literature, Ozone**

Health Effect	Population	Effect Coefficient (β)	Lower Confidence Limit	Upper Confidence Limit	Reference
Adult Onset Asthma	Males, Age 25+	1.0277	1.0142	1.0412	130
Respiratory Hospital Admissions	All Ages	1.0025	1.0018	1.0032	131
Asthma Attacks	Asthmatics	1.0018	1.0011	1.0026	132
Restricted Activity Days	Age 18 +	1.0022	1.0015	1.0029	133
Increased Symptom Days	Age 18 +	1.00014	1.000067	1.00021	134

**Table 17: Relative Risk Figures and Coefficients Derived from the Scientific Literature, Children**

Health Effect	Population	Relative Risk of Effect	Lower Confidence Limit	Upper Confidence Limit	Reference
Infant Death (PM)	0 – 1 Years	1.0039	1.0027	1.0051	135
Asthma ER Visits (Ozone)	0 – 15 Years	1.0080	1.0010	1.0186	136
Acute Bronchitis (PM)	0 – 15 Years	1.0306	1.0135	1.0502	137
Asthma Attacks (PM)	Asthmatics				
	0 – 15 Years	1.0051	1.0047	1.0056	138
Missed School Days (PM)	5 – 18 Years	0.0040	NA	NA	139

could reveal that the impacts of air pollution on human health are more extensive than portrayed here. Additionally, chronic exposure to air pollution has effects, such as reduced lung capacity, that are not quantified in this report.

- The nature of the statistical models used in scientific studies (specifically time-series studies) could lead to a small level of upward overestimation for the short-term effect estimates, as described by the Health Effects Institute.<sup>140</sup> However, the degree to which this bias may affect the studies we relied upon for our estimates is unknown.
- Estimates of the overall frequency of events like asthma attacks are often not available at the state or county level. Estimates for the U.S. population as a whole, while the best information available, may not fully reflect local conditions.
- We extrapolate population-wide

pollution exposures based on data from a network of pollution monitors around the state. This approach does not capture the full detail of individual exposures. The detail of exposure measurements and geographic differences within and among the scientific studies we rely on also affects the accuracy of our estimates. We attempted to make our exposure estimates and the exposure estimates within key scientific studies as consistent as possible.

- There may be some degree of overlap between the effects of particulate matter and ground level ozone. In other words, the estimates for the effects of each of these pollutants may not be 100 percent additive. However, while particulate matter levels are highly correlated with other air pollutants like nitrogen oxides and sulfur dioxide, they are not as correlated with ozone levels. Thus we consider the two pollutants separately within the report.

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