EFFECTS OF AIR QUALITY ON HEALTH AND INDIVIDUALS PARTICIPATING IN OUTDOOR EXERCISE

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SUMMARY

With the 2008 Olympics about to start in Beijing, China, air quality issues have been brought to the center of the international media. Multiple websites on the internet and newspaper articles discuss the poor air quality in and around Beijing and actions the Chinese government is taking to improve air quality. This paper will examine the current United States National Ambient Air Quality Standards (NAAQSs) and the effect of air quality on health and exercise. Recommendations for changes to the NAAQSs and additional studies on the effect of air quality on exercise in healthy adults will follow.

HISTORY OF THE CLEAN AIR ACT

In October 1948, a thick cloud of air pollution formed above the industrial town of Donora, Pennsylvania. The cloud, which lingered for five days, killed 20 people and caused sickness in 6,000 of the town's 14,000 people. In 1952, over 3,000 people died in what became known as London's "Killer Fog." The smog was so thick that buses could not run without guides walking ahead of them carrying lanterns.[1]

Events like these alerted people to the dangers that air pollution poses to public health. Several federal and state laws were passed, including the Clean Air Act of 1963, which established funding for the study and cleanup of air pollution. But there was no comprehensive federal response to address air pollution until Congress passed a much stronger Clean Air Act in 1970. That same year Congress created the Environmental Protection Agency (EPA) and gave it the primary role in carrying out the law. Since 1970, the EPA has been responsible for a variety of Clean Air Act programs to reduce air pollution nationwide.[2] The 1970 Clean Air Act and major amendments to the act in 1977 and 1990 serve as the backbone of efforts to control air pollution in the

United States. This law established one of the most complex regulatory programs in the country.[3]

In 1963, the first Clean Air Act was passed. The act provided permanent federal aid for research, support for the development of state pollution control agencies, and federal involvement in cross-boundary air pollution cases. An amendment to the act in 1965 directed the Department of Health, Education, and Welfare (HEW) to establish federal emission standards for motor vehicles. The 1967 Air Quality Act provided additional funding to the states, required them to establish air quality control regions, and directed HEW to obtain and make available information on the health effects of air pollutants and to identify pollution control techniques.[4]

The Clean Air Act of 1970 marked a dramatic change in the air pollution policy in the United States. Following the enactment of this law, the federal government would be the focal point of air pollution policy. This act established the framework that continues to be the foundation for air pollution control policy today in the United States.[5]

The regulatory framework of the 1970 Clean Air Act featured four key components. First, the NAAQSs were established for six major pollutants: carbon dioxide, lead, nitrogen dioxide, ground-level ozone, particulate matter, and sulfur dioxide. For each of these pollutants primary and secondary standards were set. The primary standards were designed to protect human health; secondary standards were based on protecting crops, forests, and buildings. The act specified these standards must apply to the entire country and be set by the EPA.[6]

Second, the New Source Performance Standards (NSPSs) would be set by the EPA. These standards would determine how much air pollution would be allowed by new plants in various industrial sectors.[7] Third, mobile emission standards were established to control automobile emissions. These standards were specified via statute and schedules for meeting them were written into the law. The pollutants regulated were carbon monoxide, hydrocarbons, and nitrogen oxides.[8]

The final component of the Clean Air Act dealt with the implementation of new air quality standards. Each state would be encourages to devise a state implementation plan, identifying how the state would meet the national standards. These plans had to be approved by the EPA and if a state did not have an approved plan, the EPA would administer the Clean Air Act in that state. The states were also charged with monitoring and enforcing the Clean Air Act.[9]

The 1977 amendments to the Clean Air Act dealt with three main issues: nonattainment, automobile emissions, and the prevention of air quality deterioration in areas where the air was already clean.[10] Major amendments to the Clean Air Act were also passed in the fall of 1990. These addressed acid rain, toxic air pollutants, nonattainment areas, and ozone layer depletion[11], which are not covered by this paper. In 1997, the EPA issued revised NAAQSs, setting stricter standards for ozone and particulate matter.[12] The current NAAQSs are listed on the next page. The World Health Organization (WHO) has also set air quality standards; however, the WHO standards do not address all the pollutants as the U. S. NAAQSs does and, for similar pollutants, have set different levels. WHO air standards are listed in Appendix 2.

OUTDOOR AIR POLLUTION – WHAT IS IT AND WHERE DOES IT COME FROM?

Air pollution is a phenomenon by which particles (solid or liquid) and gases contaminate the environment. Such contamination can result in health effects on the

National Ambient Air Quality Standards[13]				
	Primary Standards		Secondary Standards	
Pollutant	**Level**	**Averaging Time**	**Level**	**Averaging Time**
Carbon Monoxide	9 ppm (10 mg/m^3)	8-hour[1]	None	
	35 ppm (40 mg/m^3)	1-hour[1]		
Lead	1.5 µg/m^3	Quarterly Average	Same as Primary	
Nitrogen Dioxide	0.053 ppm (100 µg/m3)	Annual (Arithmetic Mean)	Same as Primary	
Particulate Matter (PM_{10})	150 µg/m^3	24-hour[2]	Same as Primary	
Particulate Matter ($PM_{2.5}$)	15.0µg/m^3	Annual[3] (Arithmetic Mean)	Same as Primary	
	35 µg/m^3	24-hour[4]	Same as Primary	
Ozone	0.075 ppm (2008 std)	8-hour[5]	Same as Primary	
	0.08 ppm (1997 std)	8-hour[6]	Same as Primary	
	0.12 ppm	1-hour[7] (Applies only in limited areas)	Same as Primary	
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Mean)	0.5 ppm (1300 µg/m^3)	3-hour[1]
	0.14 ppm	24-hour[1]		

Notes:
(1) Not to be exceeded more than once per year.
(2) Not to be exceeded more than once per year on average over 3 years.
(3) To attain this standard, the 3-year average of the weighted annual mean PM2.5 concentrations from single or multiple community-oriented monitors must not exceed 15.0 µg/m3.
(4) To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 µg/m3 (effective December 17, 2006).
(5) To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm. (effective May 27, 2008)
(6) (a) To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.
(b) The 1997 standard—and the implementation rules for that standard—will remain in place for implementation purposes as EPA undertakes rulemaking to address the transition from the 1997 ozone standard to the 2008 ozone standard.
(7) (a) The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is $\leq$ 1.
(b) As of June 15, 2005 EPA revoked the 1-hour ozone standard in all areas except the 8-hour ozone nonattainment Early Action Compact (EAC) Areas.

population, which could be either chronic or acute. Other effects of pollution include damage to materials (e.g., the marble statues on the Parthenon are corroded as a result of air pollution in the city of Athens), agricultural damage (such as reduced crop yield and tree growth), impairment of visibility (tiny particles scatter light very effectively), and even climate change (certain gases absorb energy, leading to global warming).[14]

Not all pollutants are a result of human activity. Natural pollutants are those that are found in nature or are emitted from natural sources. For example, volcanic activity produces sulfur dioxide and particulate pollution may derive from forest fires or windblown dust. Anthropogenic pollutants are those that are produced by humans or controlled processes. For example, sulfur dioxide is produced by fossil fuel combustion and particulate matter comes from diesel engines.[15]

Air pollutants are also classified as primary or secondary. Primary pollutants are those that are emitted directly into the atmosphere from an identifiable source. Examples include carbon monoxide and sulfur dioxide. Secondary pollutants are those that are produced in the atmosphere by chemical and physical processes from primary pollutants and natural constituents. For example, ozone is produced by hydrocarbons and oxides of nitrogen.[16]

The Clean Air Act established air quality standards for the six major pollutants list on the previous page. These are called the priority or criteria pollutants and are identified as serious threats to human health.[17] A brief description, sources, and trends of each priority pollutant follows.

Carbon Monoxide. Carbon monoxide (CO) is a colorless, odorless gas created when the carbon in certain fuels is not burn completely. These fuels include coal, natural gas, oil, gasoline, and wood. Transportation has historically been the largest source of CO emissions.[18] Nationally, CO concentrations declined 62 percent between 1990 and 2006. In 2006, CO concentrations were the lowest in the past 17 years. One site in Birmingham, Ala., showed concentrations above 9 ppm, the level of the standard.[19] Nationally, CO emissions (excluding wildfires and prescribed burning) decreased 38 percent between 1990 and 2006. Emission reductions from transportation sources were responsible for most of this decrease. CO emissions from transportation sources were reduced by more than 52 million tons over the 17 year period. Cleaner cars have contributed to cleaner air for much of the U.S.[20]

Lead. Lead is a metal that can enter the atmosphere via combustion or industrial processing of lead-containing materials. Prior to 1985, the major source of lead emissions in the United States was the leaded gasoline used in automobiles. Conversion to unleaded gasoline produced a dramatic reduction in lead emissions, virtually eliminating transportation as a source of lead emissions. Industrial processes (chiefly metals smelting and battery manufacturing) are responsible for the bulk of lead emissions.[21] Because of the phase-out of leaded gasoline, lead concentrations declined sharply during the 1980s and early 1990s. Between 1980 and 2006, concentrations of lead in the air decreased 95 percent, while emissions of lead decreased 97 percent. In 2006, only two sites had concentrations above the standard; both are associated with lead smelting operations in Herculaneum, Mo.[22]

Nitrogen Dioxide. Nitrogen dioxide (NO_2) is a reddish-brown gas that forms in the atmosphere when nitrogen oxide (NO) is oxidized. Nitrogen dioxide primarily comes from burning fuels such as gasoline, natural gas, coal, and oil. The chemical formula NO_X is used collectively to describe NO, NO_2, and other nitrogen oxides.[23] Nationally, concentrations of NO_2 decreased 30 percent between 1990 and 2006 and, in 2006, NO_2 concentrations were the lowest of the 17 year period. All recorded concentrations were well below the national standard.[24] Between 1990 and 2006, NO_x emissions decreased 29 percent. Most NO_x emissions come from transportation and fuel combustion sources, which decreased by 21 and 41 percent, respectively.[25]

Sulfur Dioxide. Sulfur dioxide (SO_2) if formed from burning fuels containing sulfur (e.g., coal or oil), extracting gasoline from oil, or extracting metals from ore. SO_2 can also dissolve in water vapor to form acid and can interact with ammonia and particles to form sulfates and other chemical products that can be harmful to people and the environment. Eighty-seven percent of SO_2 released into the air is attributable to fuel combustion; other sources include industrial facilities such as metal processing facilities. Nationally, concentrations of annual SO_2 decreased 53 percent between 1990 and 2006. Since 1990, SO_2 emissions have decreased 38 percent. The reductions in SO_2 concentrations and emissions are mainly due to controls under the EPA's Acid Rain Program.[26]

Ozone. Ozone is a gas naturally present in Earth's upper atmosphere. Ozone molecules in the stratosphere (altitudes greater than 20 miles) absorb ultraviolet radiation from the sun and prevent it from reaching the ground. Thus, stratospheric ozone is good for the environment. Tropospheric or ground level ozone is a potent air pollutant with serious health consequences.[27] Unlike other air pollutants, ground-level ozone is not emitted directly into the air. It forms on hot, sunny days due to complex chemical reactions that take place when the atmosphere contains other pollutants, primarily volatile organic compounds and nitrogen oxides. Such pollutants are called ozone precursors because their presence in the atmosphere leads to ozone creation.[28] Thus, weather plays an important role in the formation of ozone. A large number of hot, dry days can lead to higher ozone levels in any given year, even if ozone forming emissions do not increase.[29]

Nationally, ozone concentrations were 9 percent lower in 2006 than in 1990. Concentrations showed little change throughout the 1990s but a notable decline after 2002. Concentrations in 2006 were the second lowest over the 17 year period. The highest ozone concentrations were located in California and Texas. Overall, the greatest improvements were in or near urban areas while the greatest increases were in less populated or rural areas which raise concerns about ozone's detrimental effect on plants and ecosystems.[30] Unlike the other primary pollutants discussed above, there are still a significant number of sites with ozone concentrations above the standard. Because ozone if formed by the reaction of VOCs and NO_x, it is mostly a summer pollutant. During the period 1997 to 2006, summer emissions of VOCs and NO_x decreased 20 and 30 percent, respectively. The majority of these emission reductions were from transportation and fuel combustion sources. After 2002, the largest reductions were in NO_x emissions from fuel combustion sources.[31]

Particulate Matter. Particulate matter (PM) is the general term for the mixture of solid particles and/or liquid droplets found in the air. Primary particles are those emitted directly into the atmosphere (e.g., dust, dirt, and soot). Secondary particles form in the atmosphere due to complex chemical reactions among gaseous emissions and include sulfates, nitrates, ammoniums, and organic carbon compounds. For example, sulfate particulates can form when sulfur dioxide emissions from industrial facilities undergo chemical reactions in the atmosphere.[32] Sources of particle pollution are shown in table on the next page. The EPA tracks two sizes of PM: PM_{10} and $PM_{2.5}$. PM_{10} are all particles less than or equal to ten micrometers in diameter. This is roughly one-seventh the diameter of a human hair and small enough to be breathed into the lungs. $PM_{2.5}$ are the smallest of these particles (less than or equal to 2.5 micrometers in diameter. $PM_{2.5}$ is also called fine PM. Particles between 2.5 and 10 micrometers are also known as course PM. Most coarse PM is primary particles, while most fine PM is secondary particles.[34] Trends for PM_{10} and $PM_{2.5}$ will be discussed separately.

Sources of Particle Pollution [33]

Component	Sources
Sulfates	Power generation
Nitrates	Cars, trucks, and power generation
Elemental and organic carbon	Cars, trucks, heavy equipment, wildfires, waste burning, and vegetation
Crustal	Suspended soil and metallurgical operations

Note: Ammonia from sources such as fertilizer and animal feed operations contributes to the formation of sulfates and nitrates that exist in the air as ammonium sulfate and ammonium nitrate. For more information about fine particle sources, visit http://www.epa.gov/air/airtrends/aqtrnd04/pm.html.

<u>Fine PM ($PM_{2.5}$).</u> There are two standards for fine PM, an annual and daily standard. Nationally, annual fine PM concentrations declined by 14 percent between 2000 and 2006. Daily fine PM concentrations have a similar trend with a 15 percent decline.[35] Between 2000 and 2006 trends in fine PM emissions have decreased. SO2, NOx, VOC, and directly emitted $PM_{2.5}$ emissions have decreased by 16, 20, 8 and 11 percent, respectively.[36] It should be noted that weather plays an important role in the formation of fine PM. Emissions sources and the composition of fine PM differ by season. In cool months, the greater demand for heating creates more direct fine PM. In warmer months, weather conditions more conducive to fine formation create more secondary PM.[37]

<u>Coarse PM (PM_{10}).</u> Between 1990 and 2006, PM_{10} concentrations decreased 30 percent.[38] The bulk of PM_{10} in the atmosphere comes from fugitive dust and agricultural and forestry practices that stir up soil. Fugitive dust is dust thrown into the air when vehicles travel over unpaved roads and during land disturbing construction activities

such as bulldozing. In 2002, these sources were estimated to account for 85 percent of all PM_{10} emissions. However, these sources are not as great a concern to air quality. This is because soil, dust, and dirt thrown up into the air does not typically travel far from its original location or climb very far into the atmosphere.[39]

Appendix 1 includes illustrations showing the trends in concentrations of the primary pollutants. Trends in pollutant forming emissions for each primary pollutant are also shown.

HEALTH AFFECTS OF OUTDOOR AIR POLLUTION

As discussed above, the trends in outdoor pollutant concentrations have generally decreased over the past several years. Despite this progress, ground-level ozone and fine particle pollution ($PM_{2.5}$) continue to present challenges in many areas of the country. Ozone and fine particle levels are continuing to decline. In 2006, 8-hour ozone concentrations were 9 percent lower than in 1990, and annual $PM_{2.5}$ concentrations were 14 percent lower than in the year 2000. But that same year, more than 100 million people lived in counties that exceeded national air quality standards for ozone or $PM_{2.5}$.[40] While air quality has generally improved, it is important to understand the effects of poor air quality on health.

Lead. Lead is a particularly dangerous pollutant because it accumulates in the blood, bones, and soft tissues of the body. It can adversely affect the nervous system, kidneys, liver, and other organs. Excessive concentrations are associated with neurological impairments, mental retardation, and behavioral disorders.[41] Lead exposure also affects the oxygen carrying capacity of the blood. The lead effects of greatest concern from current exposures are neurological effects in children. Infants and young children are especially sensitive to even low levels of lead, which may contribute to behavioral problems, learning deficits, and lower intelligence quotients.[42]

Nitrogen Dioxide. Short-term exposures (e.g., less than three hours) to low level of NO_2 may decrease lung function in individuals with pre-existing respiratory illnesses. Long-term exposures well above ambient NO_2 levels may cause irreversible changes in lung structure.[43] NO_x reacts with ammonia and water droplets in the atmosphere to form nitric acid and other chemicals that are harmful to human health. Inhalation of these particles can interfere with respiratory processes and damage lung tissue. Particles inhaled deeply into the lungs can cause or aggravate respiratory conditions such as bronchitis and emphysema.[44] For example, ground level ozone forms when NOx and VOCs react in the presence of sunlight.[45]

Carbon Monoxide. CO enters the bloodstream through the lungs and reduces oxygen delivery to the body's organs and other tissues. Higher levels of CO are most serious for those suffering from heart disease such as angina, clogged arteries, or congestive heart failure. For a person with heart disease, a single exposure to CO at high levels may cause chest pain and reduce the person's ability to exercise; repeated exposures may contribute to other cardiovascular effects. People who breathe high levels of CO can develop vision problems, reduced ability to work, reduced manual dexterity, and difficulty performing complex tasks. At even higher levels, CO can cause death.[46]

Sulfur Dioxide. SO_2 causes a wide variety of health and environmental impacts. Particularly sensitive groups include asthmatics who are active outdoors, children, the elderly, and people of any age with heart or lung disease. Longer-term exposures to high levels of SO_2 gases and related particles have been shown to cause respiratory illness and aggravate existing heart disease. Sulfate particles can gather in the lungs, causing respiratory symptoms and disease, difficulty in breathing, and premature death. Sulfate particles are the major cause of reduced visibility in many parts of the U.S., including national parks. SO_2 is also a major contributor to acid rain.[47]

Ozone. Even the smallest amounts of ozone can cause breathing difficulties. Ozone exposure can cause serious problems with lung functions, leading to infections, chest pain, and coughing. According to the Environmental Protection Agency, ozone exposure is linked with increased emergency room visits and hospital admissions due to such respiratory problems as lung inflammation and asthma. Ozone causes or aggravates these problems, particularly in people working outdoors, the elderly, and children. Children are especially susceptible to the harmful effects of ozone because they spend a great deal of time outside and their lungs are still developing.[48]

Particulate Matter. Particle pollution, especially fine particles, contains microscopic solids or liquid droplets that are so small they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of health problems including (1) increases in respiratory symptoms such as irritation of the airways, coughing, or difficulty breathing; (2) decreased lung function; (3) aggravated asthma; (4) development of chronic bronchitis; (5) irregular heartbeat; (6) heart attacks; and (7) premature death. People with heart or lung disease, the elderly, and children are at the highest risk from exposure to particles. In addition to health problems, particle pollution is the major cause of reduced visibility and ecosystem damage in many parts of the U.S., including national parks and wilderness areas.[49]

AFFECTS OF OUTDOOR AIR POLLUTION ON EXERCISE AND THE OLYMPICS

Considering the health affects of the six primary outdoor air pollutants discussed above, the question of would the health effects of poor air quality be worse for athletes or others that exercise outside. Recent news articles would imply there is. Within the United States, a California newspaper, the Auburn Journal, reported:

> Lightning, fire, and smoke did what snow, heat and the test of time could not. In a move unprecedented since the Western States Endurance Run's first 100-mile trek from Squaw Valley to Auburn in 1977, the event was called off Wednesday. Tim Twietmeyer, Western States Run board president, said air quality and safety were key reasons for the decision."[50]

Poor air quality due to forest fires was cited as one of the reasons for cancelling the race.

On an international note, poor air quality is a concern with the upcoming 2008 Olympic Games in Beijing, China. As reported in the washingtonpost.com:

> The International Olympic Committee acknowledged for the first time yesterday that air pollution could affect the health and performance of athletes at this summer's Olympics in Beijing and said it would monitor air quality daily during the Games to determine whether to postpone certain outdoor events. Air-quality problems could decrease the potential for world records and peak performances in all sports while creating a possible health risk in outdoor endurance events such as the marathon, triathlon, and road cycling, the committee's highest-ranking medical official said.[51]

In fact, Haile Gebrselassie, the world-record holder in the marathon and perhaps distance running's biggest name stated that he would not compete in the marathon at the Olympics in August because of concerns about the effects of the city's pollution, heat and humidity.[52] Gebrselassie has exercise-induced asthma and he feared that the conditions expected in China could damage his body and prevent him from competing on a high level in the future.[53] China understands that air quality is a potential issue and recognizes that automobile emissions are heavily to blame and is taking action. Half of all cars belonging to the government and Communist Party were ordered off the Beijing's clogged roads to help clean the city's air. The automobile ban is part of an antipollution plan that also will halt construction and heavy industry during the Olympics.[54]

But, are the extreme actions of banning cars and trucks and securing industrial operations necessary? Did Gebrselassie make the right decision? The basic reason that athletes and others who exercise outdoors should be concerned about ambient air quality is based on air intake. Dr. Kenneth Rundell, the director of the Human Performance Laboratory at Marywood University in Scranton, Pennsylvania, said, "Athletes typically take in 10 to 20 times as much air," and thus pollutants, with every single breath as sedentary people do.[55] Further, mouth breathing during exercise bypasses the nasal passages, the body's natural air filter. This means that when exercising in polluted air, athletes increase their contact with pollutants, and increase their vulnerability to health damage.[56]

In 1990, the three main pollutants identified that could affect exercise were ozone, sulfur dioxide, and carbon dioxide.[57] Though the production of these pollutants differ their immediate effects on the body are similar. They displace oxygen in the bloodstream, and/or irritate the airways. Consequently, exercising in polluted air is like exercising when one is less fit: fatigue sets in earlier, aerobic activity is reduced, and your threshold for experiencing symptoms of heart and lung disease is lowered.[58]

However, in 2001, the American Lung Association published a study identifying that current levels of particulate air pollution are harmful to human health. In this study, the affects of particulate matter on multiple health conditions and age groups were discussed. One study involved a controlled exposure to particulate matter on young, healthy volunteers. The study stated:

> Volunteers alternated between moderate exercise and rest over a two-hour period in a chamber with high particle concentrations. No symptoms or decrements in pulmonary function were noted. However, eighteen hours after exposure, lung tissue had a higher concentration of neutrophis, a marker of inflammation. Blood work indicated a higher concentration of fibrinogen, which is a risk factor for clotting and heart attacks.[59]

Two studies published in *Inhalation Toxicology* confirmed that particulate matter intake is higher during periods of exercise. In 2003, a study of ultrafine particle deposition in humans during rest and exercise concluded:

> In summary, these studies confirm that the deposition fraction of ultrafine particles is high in healthy subjects, and increased with decreasing particle size. Deposition increases further with exercise, to a greater degree than predicted by modeling estimates. The combination of increased particle intake, increased deposition and the high deposition of ultrafine particles in the alveolar region indicates that ultrafine particles burden to the alveolar epithelium is significantly greater during exercise.[60]

In 2007, another study of ultrafine particles deposition during rest and exercise found that:

> Combining the effects of exercise and hygroscopicity, an average exercising exposed to 100-nm hydrophobic ultrafine particles may receive a 16 times higher dose than a relaxed person exposed to an equal amount of hygroscopic particles with the same dry size.[61]

The above studies confirm that individuals participating in outdoor exercise will increase their absorption of particulate matter and other airborne pollutants. However, only limited studies on the affects of poor air quality due to exercise have been done. In 2002, a study published in *Circulation* stated an association between fine and ultrafine particulate air pollution and the risk of exercised induced ST-segment depression among subjects with coronary heart disease was observed.[62] [The ST-segment is the portion of an electrocardiogram between the end of the QRS complex and the beginning of the T wave and represents the period of slow repolarization of the ventricles.[63] Depressed ST-segments may indicate coronary ischemia.[64]]

In 2007, an article in the *New York Times* documented a review of pollution studies worldwide conducted by the University of Brisbane, Australia, in 2004 found that during exercise, low concentration of pollutants in the air caused lung damage similar to that caused by similar exposure to high concentrations for people not working out. The article also stated that most experts agree that the greatest overall public health impact of air pollution comes from fine particles. One study involved 30 healthy volunteers who rode bicycles inside a laboratory for 30 minutes, while breathing piped-in diesel exhaust at levels approximately those along a city highway at rush hour. Afterward, the researchers did a “kind of stress test” of the blood vessels in the particpants’ forearms. The blood vessels were found to be abnormally dilated, meaning blood and oxygen could not flow easily to the muscles. Also, levels of tissue plasminogen activator, or tPA, a naturally-occuring protein that dissolves blood clots, had fallen. These are ideal conditions for a heart attack. A heart attack can start when arteries constrict and a clot forms.[65]

A more recent study of the amount of work done individuals during exercise did not show an immediate effect on performance. The researchers found that performance was affected three days after the initial exposure, suggesting that either the pulmonary system and/or the microvascular system were affected from the first high particulate matter exposure exercise.[66] This study also identified that no information concerning the effects on particulate matter on exercise performance in healthy individuals exists.[67]

CONCLUSIONS AND RECOMMENDATIONS

Research clearly indicates there is a link between air quality and health and that the affect of poor air quality on individuals who exercise outdoors should be have more significant health affects in the long term due to the increased deposition of pollutants in the lungs. However, most studies on air quality address the affects of poor air quality on children and the elderly. Few studies address the affects of poor air quality, especially the primary pollutants, on athletes or otherwise healthy individuals who exercise outdoors. Further research to determine the affects of poor air quality on people who exercise is required. Based on the lack of studies of the affect of poor air quality on individuals exercising outdoors and the acknowledgement that particulate matter intake may have the greatest adverse affect on health, I offer five recommendations.

First, the United States should adopt the World Health Organization (WHO) air quality standards for ozone, particulate matter, nitrogen dioxide, and sulfur dioxide (the

WHO air quality standards do not include lead or carbon monoxide). The WHO air quality standards, listed in Appendix 2, were revised in 2005 and are more restrictive than the NAAQSs. Based on the declining trends of pollutants in the United States, the Environmental Protection Agency should determine the impacts of adopting the WHO air quality standards and develop implementation plans for achieving them.

Second, the Environmental Protection Agency should revise the NAAQSs to be a region based standard vice a national standard. Ozone and particulate matter can be greatly affected by weather and weather patterns. As such, ozone precursors and particulate matter emissions from one location can be transported to another area, resulting in poor quality based on the cumulative effect of emissions from both regions. For example, emissions in Denver, Colorado could be transported to Chicago, Illinois due to wind patterns and, when combined with emissions from the Chicago area, result in unhealthy air quality. While each state or region within the United States can adopt more stringent standards than the NAAQSs, the Environmental Protection Agency should continue to investigate the effect of weather on pollutant dispersal and develop a regional or state based approach for determining air quality standards.

Third, funding should be made available to perform more studies on the short-term and long-term effects of air quality on athletes or individuals exercising outdoors. Few studies exist addressing the effects of ozone and particulate matter on relatively healthy adults exercising outdoors. The Center for Disease Control recently reported adult obesity is increasing in the United States and is encouraging people to engage in more physical activity.[68] If more people begin to exercise outdoors, the affects of poor air quality could have significant impact on health and healthcare costs in the long term.

Obtaining a better understanding of the affects of air quality on outdoor exercise should be a priority to mitigate any potential long-term issues.

Fourth, society should continue efforts to develop ways to reduce emissions. Transportation sources continue to be a significant contributor to poor air quality. Developing low-emission vehicles or alternate fuel vehicles should continue to be a focal point in the fight to improve air quality as well as encouraging the use carpooling and mass transit. However, developers should include the all aspects of alternate fuels when developing alternate fuel vehicles. For example, increasing the number of all electric cars being used may not be beneficial if the amount of coal burned in power plants significantly increases in order charge the batteries in the car.

Finally, the Environmental Protection Agency should make better known the list of actions an individual can do to help improve air quality. This list, while available via the internet, may not be well known to the general population. These actions are listed in Appendix 3. On days when air quality approaches unhealthy levels (which are defined by the cross-agency U.S. Government website http://www.airnow.gov), news organizations should highlight the existence of this list, identify where it can be found, and encourage people to review the list and implement as many items as possible. After all, it is the individuals own interest to improve the air quality around them since it is their health that would benefit.

Gebrselassie, the organizers of the Western States Endurance Run, and China made the right decisions. Even though research is lacking, there is sufficient empirical evidence to suggest that outdoor exercise and athletic competitions undertaken during periods of poor air quality could have adverse consequences to the participants. Athletes themselves have documented the immediate effects of poor air quality.

> As one cyclist wrote on SoCalCycling.com, “During the summer months, I have to ride in the morning and be home no later than 11, otherwise I will feel miserable and cough all day long.[69]

Until we have official studies documenting the affect of poor air quality on those who workout outdoors, individuals will need to determine the risk of outdoor exercise based on their own experience or the experience of others.

The EPA reports that, since 1980, emissions of the six principal pollutants have declined significantly. All of this progress has occurred while the U.S. economy continued to grow, Americans drove more miles, and population and energy use increased. These emission reductions resulted from a variety of control programs, from regulations at the federal, state, local, and regional level to voluntary partnerships between federal, state, local, and tribal governments, academia, industrial groups, and environmental organizations.[70] These control programs and partnerships should be continued to ensure that focus on air quality improvements is not lost and that we, as a people and a nation, continue to take cost-effective and efficient actions to improve the air we breathe.

APPENDIX 1

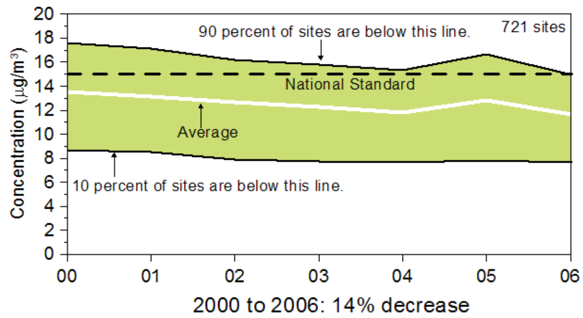
Air Quality Trends

excerpted from

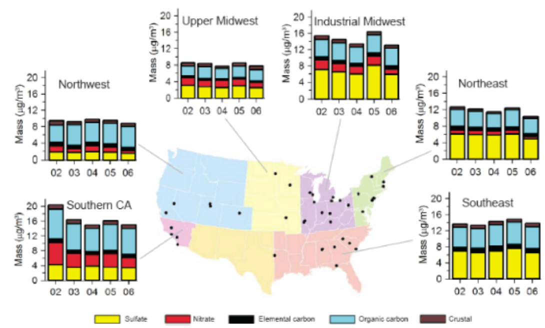
Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 8-24.

The following graphs demonstrate the current trends in air quality of the six primary pollutants. The two types of particulate matter ($PM_{2.5}$ and PM_{10}) will be covered in separate sections.

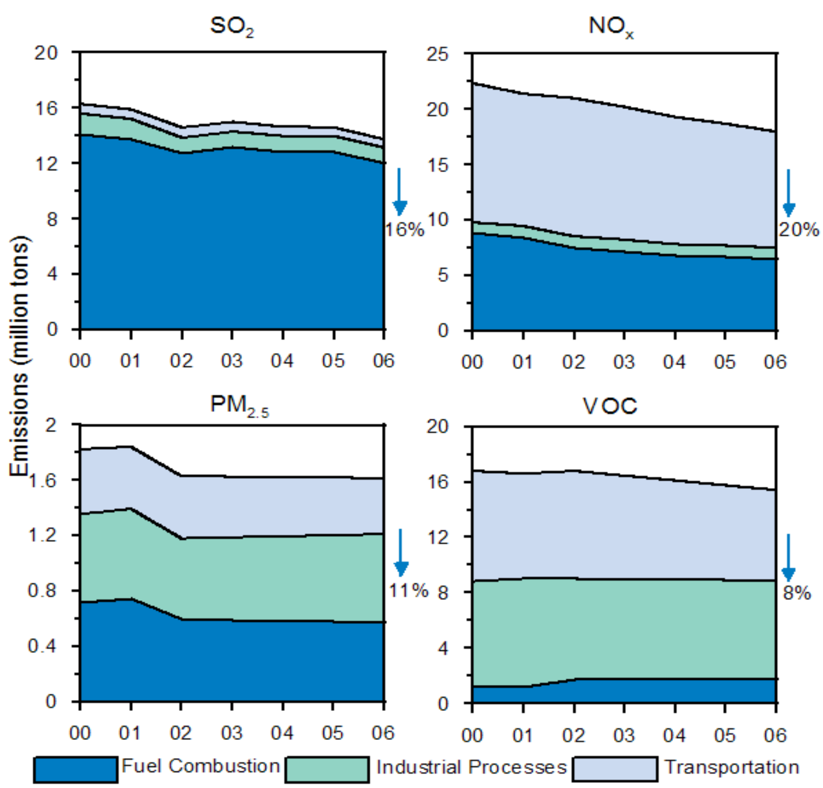
PARTICULATE MATTER – $PM_{2.5}$



National $PM_{2.5}$ air quality trend, 2000-2006 (annual average).

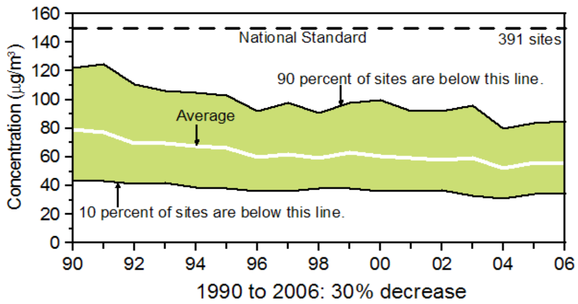


Regional trends in annual $PM_{2.5}$ composition in µg/m^3, 2002-

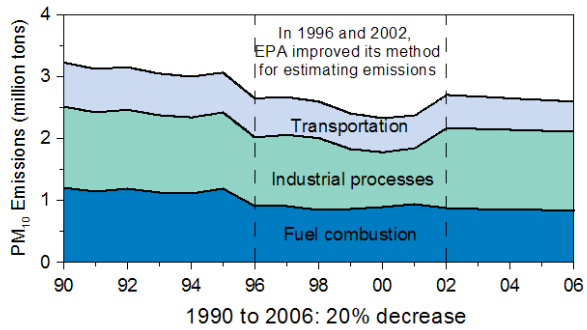


National trends in annual direct $PM_{2.5}$ and $PM_{2.5}$ - forming emissions, 2000-2006.

PARTICULATE MATTER – PM_{10}

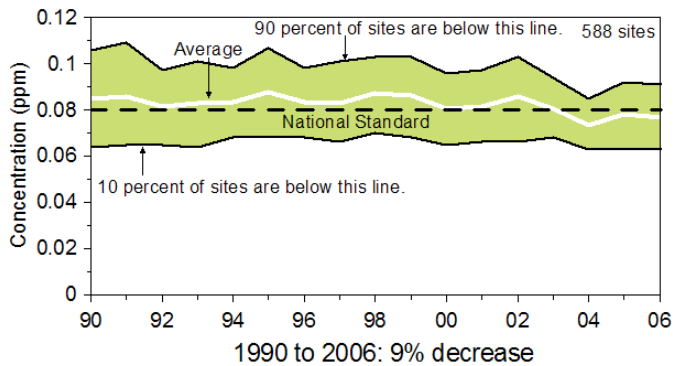


National PM_{10} air quality trend, 1990-2006 (second maximum 24-hour concentration).

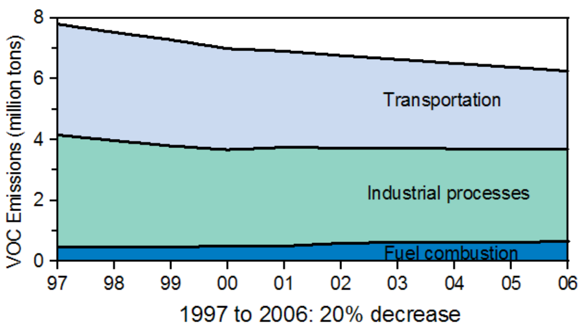


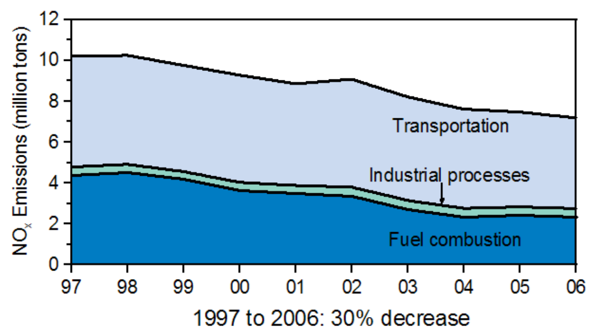
National trends in direct PM_{10} emissions, 1990-2006.

OZONE



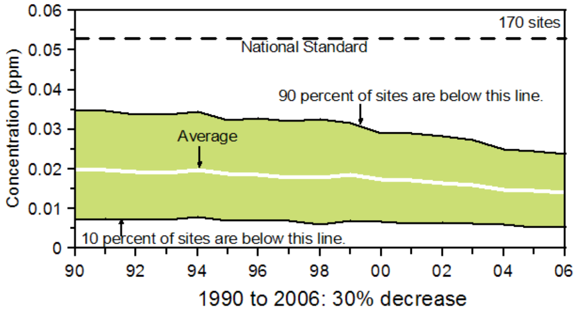
National 8-hour ozone air quality trend, 1990-2006 (average of annual fourth highest daily maximum 8 - hour concentrations).



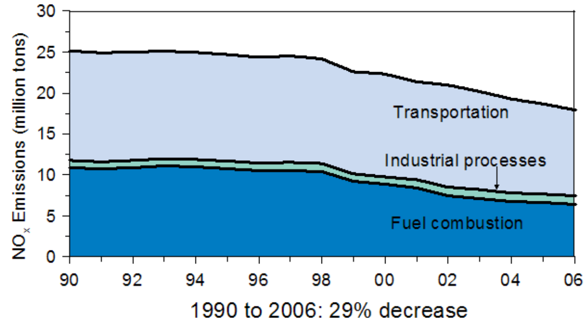


National trends in summertime ozone-forming emissions, 1997-2006.

NITROGEN DIOXIDE

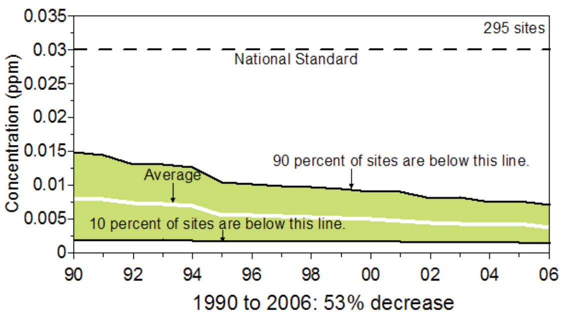


National NO_2 air quality trend, 1990-2006 (annual average).

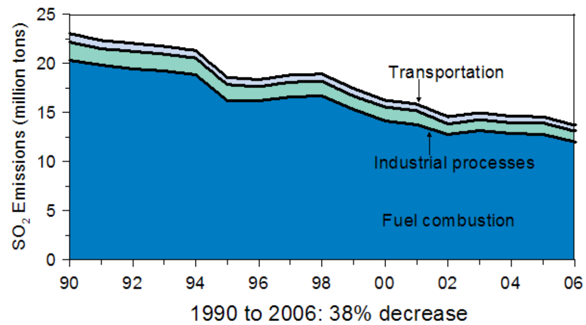


National trends in annual NO_x emissions, 1990-2006.

SULFUR DIOXIDE

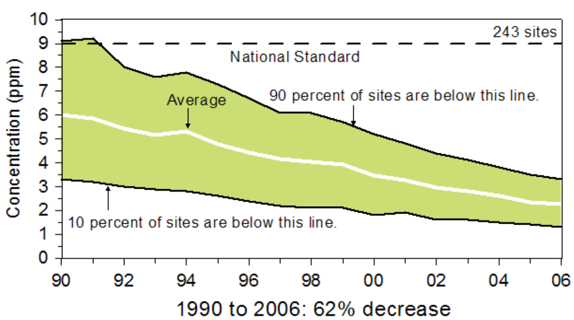


National SO_2 air quality trend, 1990-2006 (annual average).

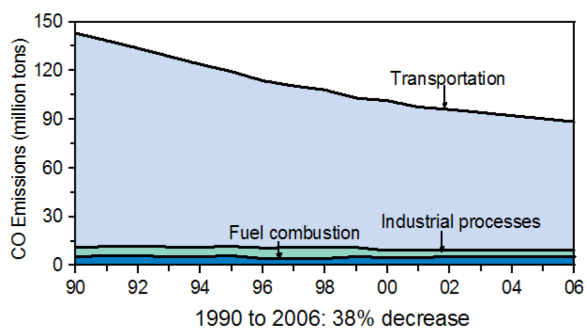


National trends in annual SO_2 emissions, 1990-2006.

CARBON MONOXIDE

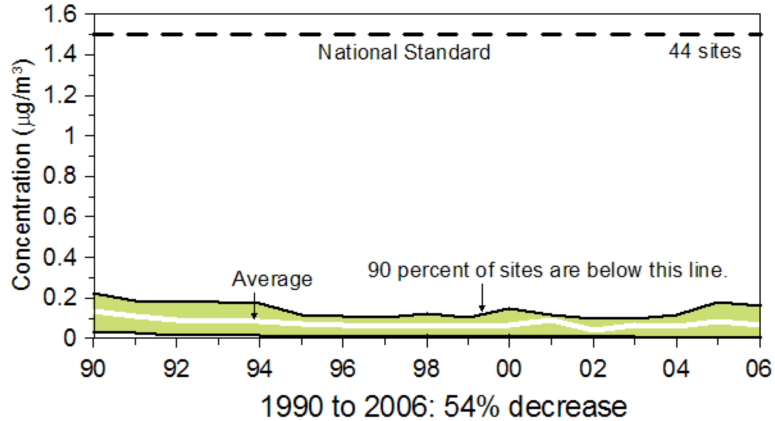


National CO air quality trend, 1990-2006 (second maximum 8-hour average).



National trends in annual CO emissions, 1990-2006.

LEAD



National lead air quality trend, 1990-2006 (maximum quarterly average).

APPENDIX 2

World Health Organization Air Quality Standards

excerpted from

World Health Organization, *WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide* (Geneva: World Health Organization, 2006), 9, 14, 16, 18.

World Health Organization Quality Standards

	Standards	
Pollutant	**Level**	**Averaging Time**
Particulate Matter (PM_{10})	20 µg/m^3	Annual Mean
	50 µg/m^3	24-hour Mean
Particulate Matter ($PM_{2.5}$)	10.0µg/m^3	Annual Mean
	25 µg/m^3	24-hour Mean
Ozone	100 µg/m^3	8-hour Mean
Nitrogen Dioxide	40 µg/m^3	Annual Mean
	200 µg/m^3	1-hour Mean
Sulfur Dioxide	20 µg/m^3	24-hour Mean
	500 µg/m^3	10-minute Mean

APPENDIX 3

ACTIONS AN INDIVIDUAL CAN DO TO IMPROVE AIR QUALITY

excerpted from

U. S. Environmental Protection Agency, “Ways to Reduce Air Pollution,” http://www.epa.gov/air/caa/peg/reduce.html (accessed July 18, 2008).

Ways to Reduce Air Pollution

At Home

- Conserve energy - turn off appliances and lights when you leave the room.
- Recycle paper, plastic, glass bottles, cardboard, and aluminum cans. (This conserves energy and reduces production emissions.)
- Keep woodstoves and fireplaces well maintained. You should also consider replacing old wood stoves with EPA-certified models. Visit www.epa.gov/woodstoves.
- Plant deciduous trees in locations around your home to provide shade in the summer, but to allow light in the winter.
- Buy green electricity-produced by low-or even zero-pollution facilities.
- Connect your outdoor lights to a timer or use solar lighting.
- Wash clothes with warm or cold water instead of hot.
- Lower the thermostat on your water heater to 120°F.
- Use low-VOC or water-based paints, stains, finishes, and paint strippers.
- Test your home for radon-a dangerous, radioactive gas that is odorless and tasteless. If the test shows elevated levels of radon, the problem can be fixed cost effectively. Visit www.epa.gov/radon.
- Choose not to smoke in your home, especially if you have children. If you or your visitors must smoke, then smoke outside. Visit www.epa.gov/smokefree.

Buy Smart

- Buy ENERGY STAR products, including energy efficient lighting and appliances. They are environmentally friendly products. For more information, visit www.energystar.gov or call 1-888-STAR-YES.
- Choose efficient, low-polluting models of vehicles. Visit www.epa.gov/greenvehicles.
- Choose products that have less packaging and are reusable.
- Shop with a canvas bag instead of using paper and plastic bags.
- Buy rechargeable batteries for devices used frequently.

Drive Wise

Plan your trips. Save gasoline and reduce air pollution.

- Keep tires properly inflated and aligned.
- In the summertime, fill gas tank during cooler evening hours to cut down on evaporation. Avoid spilling gas and don't "top off" the tank. Replace gas tank cap tightly.
- Avoid waiting in long drive-thru lines, for example, at fast-food restaurants or banks. Park your car and go in.
- When possible, use public transportation, walk, or ride a bike.
- Get regular engine tune ups and car maintenance checks (especially for the spark plugs).

- Use an energy-conserving (EC) grade motor oil.
- Ask your employer to consider flexible work schedules or telecommuting.
- Report smoking vehicles to your local air agency.
- Join a carpool or vanpool to get to work.

For Your Health

- Check daily air quality forecasts, which tell how clean or polluted your air is, and the associated health concerns. Visit www.airnow.gov.
- Remove indoor asthma triggers from your home and avoid outdoor triggers in order to effectively control your asthma. Visit www.epa.gov/asthma to learn more about asthma triggers and ways to avoid them.
- Minimize your sun exposure. Wear sun block and UV protection sunglasses. To find out about current forecasts of UV where you live, go to www.epa.gov/sunwise/uvindex.html.

ENDNOTES

[1] U. S. Environmental Protection Agency, “Understanding the Clean Air Act,” under “Brief History of the Clean Air Act,” http://www.epa.gov/air/caa/peg/understand.html (accessed June 10, 2008).

[2] U. S. Environmental Protection Agency, “Understanding the Clean Air Act,” under “Brief History of the Clean Air Act,” http://www.epa.gov/air/caa/peg/understand.html (accessed June 10, 2008).

[3] Christopher McGrory Klyza and Paula Anne Ford-Martin, “Clean Air Act (1963, 1970, 1990),” *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), first paragraph.

[4] Christopher McGrory Klyza and Paula Anne Ford-Martin, “Clean Air Act (1963, 1970, 1990),” *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), second paragraph.

[5] Christopher McGrory Klyza and Paula Anne Ford-Martin, “Clean Air Act (1963, 1970, 1990),” *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), third paragraph.

[6] Christopher McGrory Klyza and Paula Anne Ford-Martin, “Clean Air Act (1963, 1970, 1990),” *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), fourth paragraph.

[7] Christopher McGrory Klyza and Paula Anne Ford-Martin, “Clean Air Act (1963, 1970, 1990),” *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), fifth paragraph.

[8] Christopher McGrory Klyza and Paula Anne Ford-Martin, “Clean Air Act (1963, 1970, 1990),” *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale.

http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), sixth paragraph.

9 Christopher McGrory Klyza and Paula Anne Ford-Martin, "Clean Air Act (1963, 1970, 1990)," *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), seventh paragraph.

10 Christopher McGrory Klyza and Paula Anne Ford-Martin, "Clean Air Act (1963, 1970, 1990)," *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), eighth paragraph.

11 Christopher McGrory Klyza and Paula Anne Ford-Martin, "Clean Air Act (1963, 1970, 1990)," *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), tenth paragraph.

12 Christopher McGrory Klyza and Paula Anne Ford-Martin, "Clean Air Act (1963, 1970, 1990)," *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008), twelfth paragraph.

13 U. S. Environmental Protection Agency, "National Ambient Air Quality Standards (NAAQS)," http://www.epa.gov/air/criteria.html (accessed June 10, 2008).

14 Christos Christoforou, "Air Pollution," in *Pollution A to Z,* vol. 1, ed. Richard M. Stapleton, Patricia Hemminger, and Susan L. Senecah (New York: Macmillan Reference USA, 2004), 30.

15 Christos Christoforou, "Air Pollution," in *Pollution A to Z,* vol. 1, ed. Richard M. Stapleton, Patricia Hemminger, and Susan L. Senecah (New York: Macmillan Reference USA, 2004), 32.

16 Christos Christoforou, "Air Pollution," in *Pollution A to Z,* vol. 1, ed. Richard M. Stapleton, Patricia Hemminger, and Susan L. Senecah (New York: Macmillan Reference USA, 2004), 32.

17 Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 18.

[18] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 19.

[19] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 22.

[20] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 22.

[21] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 20.

[22] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 24.

[23] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 21.

[24] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 21.

[25] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 21.

[26] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 23.

[27] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 22.

[28] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 22.

[29] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 11.

[30] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 8.

[31] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 11.

[32] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 23.

[33] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 19.

[34] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 23-24.

[35] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 14.

[36] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 17.

[37] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 18.

[38] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 20.

[39] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 24.

[40] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 1.

[41] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 20-21.

[42] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 24.

[43] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 21.

[44] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 21.

[45] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 21.

[46] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 22.

[47] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 23.

[48] Kim Master Evans, *The Environment: A Revolution in Attitudes* (Detroit: Thomson Gale, 2006), 23.

[49] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 14.

[50] Gus Thomson, "Western States Endurance Run canceled," *Auburn Journal*, June 25, 2008, http://auburnjournal.com/detail/87389.html (accessed July 13, 2008).

[51] Amy Shipley, "Olympic Officials Want to Clear the Air," *The Washington Post,* March 18, 2008.

[52] Katie Thomas, "Citing Pollution, Gebrselassie Opts Out of Olympic Marathon," *New York Times,* March 11, 2008, http://www.nytimes.com/2008/03/11/sports/othersports/11olympics.html_r=2&oref=slogin&oref=slogin (accessed June 10, 2008).

[53] Katie Thomas, "Citing Pollution, Gebrselassie Opts Out of Olympic Marathon," *New York Times,* March 11, 2008, http://www.nytimes.com/2008/03/11/sports/othersports/11olympics.html_r=2&oref=slogin&oref=slogin (accessed June 10, 2008).

[54] Associated Press, "China Limits Beijing Cars," *Express: A Publication of the Washington Post,* June 24, 2008.

[55] Gretchen Reynolds, "Air pollution holds risks for athletes who exercise outdoors," *International Herald Tribune*, July 12, 2007, http://www.iht.com/bin/print.php?id=6628800 (accessed June 19, 2008).

[56] American Lung Association, "Air Pollution and Exercise," http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=36292 (accessed June 10, 2008).

[57] Ralph LaForge, "Air pollution & exercise," *Executive Health Report* 26, no. 10 (July 1990): 6, http://galenet.galegroup.com/servlet/HWRC/hits?r=d&origSearch=false&o=&bucket=per&rlt=2&n=10&l=d&basicSearchOption=KE&items=0&c=13&tcit=0_1_0_0_0_0&docNum=A9156099&locID=chan86036&secondary=false&t=RK&s=1&SU=pollution+exercise (accessed July 13, 2008).

[58] Ralph LaForge, "Air pollution & exercise," *Executive Health Report* 26, no. 10 (July 1990): 6, http://galenet.galegroup.com/servlet/HWRC/hits?r=d&origSearch=false&o=&bucket=per&rlt=2&n=10&l=d&basicSearchOption=KE&items=0&c=13&tcit=0_1_0_0_0_0&docNum=A9156099&locID=chan86036&secondary=false&t=RK&s=1&SU=pollution+exercise (accessed July 13, 2008).

[59] American Lung Association, *Selected Key Studies on Particulate Matter and Health: 1997-2001* (Washington, D.C.: American Lung Association, 2001), 14.

[60] Christopher C. Daigle et al., "Ultrafine Particle Deposition in Humans During Rest and Exercise," *Inhalation Toxicology* 15 (2003): 551.

[61] Jakob Löndahl et al., "Size-Resolved Respiratory-Tract Deposition of Fine and Ultrafine Hydrophobic and Hygroscopic Aerosol Particles During Rest and Exercise," *Inhalation Toxicology* 19 (2007): 115.

[62] Juha Pekkanen et al., "Particulate Air Pollution and Risk of ST-Segment Depression During Repeated Submaximal Exercise Tests Among Subjects With Coronary Heart Disease," *Circulation* 106 (2002): 938.

[63] The Free Dictionary, "S-T segment," Farlex, http://medical-dictionary.thefreedictionary.com/S-T+segment (accessed July 18, 2008).

[64] Frank G. Yanowitz, "X. ST Segment Abnormalities," The Alan E. Lindsay ECG Learning Center in Cyberspace, http://library.med.utah.edu/kw/ecg/ecg_outline/Lesson10/index.html (accessed July 18, 2008).

[65] Gretchen Reynolds, "For Athletes, an Invisible Traffic Hazard," *New York Times*, July 12, 2007, http://www.nytimes.com/2007/07/12/fashion/12Fitness.html?_r=1&scp=1&sq=athletes%20invisible%20traffic%20hazard&st=cse&oref=sloginh (accessed July 13, 2008).

[66] Kenneth W. Rundell and Renee Caviston, "Ultrafine and Fine Particulate Matter Inhalation Decrease Exercise Performance in Healthy Subjects," *Journal of Strength and Conditioning Research* 22, no. 1 (January 2008): 4-5.

[67] Kenneth W. Rundell and Renee Caviston, "Ultrafine and Fine Particulate Matter Inhalation Decrease Exercise Performance in Healthy Subjects," *Journal of Strength and Conditioning Research* 22, no. 1 (January 2008): 2.

[68] Department Of Health And Human Services, Centers for Disease Control and Prevention, *Latest CDC Data Show More Americans Report Being Obese,* Press Release, Office of Enterprise Communication, (Washington, D.C., July 17, 2008).

[69] Gretchen Reynolds, "Air pollution holds risks for athletes who exercise outdoors," *International Herald Tribune*, July 12, 2007, http://www.iht.com/bin/print.php?id=6628800 (accessed June 19, 2008).

[70] Environmental Protection Agency, Office of Air Quality, Planning and Standards, Air Quality Assessment Division, *Latest Findings on National Air Quality: Status and Trends Through 2006* (Washington, D.C., 2008), 6.

REFERENCES CONSULTED

American Lung Association. "Air Pollution and Exercise." http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=36292 (accessed June 10, 2008).

American Lung Association. *Selected Key Studies on Particulate Matter and Health: 1997-2001.* Washington, D.C.: American Lung Association, 2001.

Associated Press. "China Limits Beijing Cars." *Express: A Publication of the Washington Post,* June 24, 2008.

Christoforou, Christos. "Air Pollution." In *Pollution A to Z,* Vol. 1, ed. Richard M. Stapleton, Patricia Hemminger, and Susan L. Senecah, 30-38. New York: Macmillan Reference USA, 2004.

Daigle, Christopher C., David C. Chalupa, F. Raymond Gibb, Paul E. Morrow, Günter Oberdörster, Mark J, Utell, and Mark W. Frampton. "Ultrafine Particle Deposition in Humans During Rest and Exercise." *Inhalation Toxicology* 15 (2003): 539-552.

Evans, Kim Masters. *The Environment: A Revolution in Attitudes.* Detroit: Thomson Gale, 2006.

Gerdes, Louise I., ed. *Opposing Viewpoints: Pollution.* Detroit: Thomson Gale, Greenhaven Press, 2006.

Kidd, Jerry S., and Renee A. Kidd. *Air Pollution: Problems and Solutions.* New York: Chelsea House, 2006.

Klyza, Christopher McGrory and Ford-Martin, Paula Anne. "Clean Air Act (1963, 1970, 1990)," *Environmental Encyclopedia* ed. Marci Bortman and Peter Brimblecombe. 3rd ed. (Detroit: Gale, 2003) *Science Resource Center* Gale. http://galenet.galegroup.com/sevelet/SciRC?ste=1&docNum=CV2644150271 (accessed June 29, 2008).

LaForge, Ralph. "Air pollution & exercise." *Executive Health Report* 26, no. 10 (July 1990): 6, http://galenet.galegroup.com/servlet/HWRC/hits?r=d&origSearch=false&o=&bucket=per&rlt=2&n=10&l=d&basicSearchOption=KE&items=0&c=13&tcit=0_1_0_0_0_0&docNum=A9156099&locID=chan86036&secondary=false&t=RK&s=1&SU=pollution+exercise (accessed July 13, 2008).

Löndahl, Jakob, Andreas Massling, Joakim Pagels, Erik Swietlicki, Elvira Vaclavik, and Steffen Loft. “Size-Resolved Respiratory-Tract Deposition of Fine and Ultrafine Hydrophobic and Hygroscopic Aerosol Particles During Rest and Exercise.” *Inhalation Toxicology* 19 (2007): 109-116.

Pekkanen, Juha, Annette Peters, Gerard Hoek, Pekka Tiittanen, Bret Brunekreef, Jeroen de Hartog, Joachim Heinrich, Angela Ibald-Mulli, Wolfgang G. Kreyling, Timo Lanki, Kirsi L. Timonen, Esko Vanninen. “Particulate Air Pollution and Risk of ST-Segment Depression During Repeated Submaximal Exercise Tests Among Subjects With Coronary Heart Disease.” *Circulation* 106 (2002): 933-938.

Reynolds, Gretchen. “Air pollution holds risks for athletes who exercise outdoors.” *International Herald Tribune*, July 12, 2007, http://www.iht.com/bin/print.php?id=6628800 (accessed June 19, 2008).

Reynolds, Gretchen. “For Athletes, an Invisible Traffic Hazard.” *New York Times*, July 12, 2007, http://www.nytimes.com/2007/07/12/fashion/12Fitness.html?_r=1&scp=1&sq=athletes%20invisible%20traffic%20hazard&st=cse&oref=sloginh (accessed July 13, 2008).

Rundell, Kenneth W., and Renee Caviston. “Ultrafine and Fine Particulate Matter Inhalation Decrease Exercise Performance in Healthy Subjects.” *Journal of Strength and Conditioning Research* 22, no. 1 (January 2008): 2-5.

Shipley, Amy. “Olympic Officials Want to Clear the Air.” *The Washington Post,* March 18, 2008.

The Free Dictionary. “S-T segment.” Farlex. http://medical-dictionary.thefreedictionary.com/S-T+segment (accessed July 18, 2008).

Thomas, Katie. “Citing Pollution, Gebrselassie Opts Out of Olympic Marathon.” *New York Times,* March 11, 2008, http://www.nytimes.com/2008/03/11/sports/othersports/11olympics.html_r=2&oref=slogin&oref=slogin (accessed June 10, 2008).

Thomson, Gus. “Western States Endurance Run canceled.” *Auburn Journal*, June 25, 2008, http://auburnjournal.com/detail/87389.html (accessed July 13, 2008).

U. S. Department Of Health And Human Services. Centers for Disease Control and Prevention. *Latest CDC Data Show More Americans Report Being Obese,* Press Release, Office of Enterprise Communication. Washington, D.C., July 17, 2008.

U. S. Environmental Protection Agency. National Ambient Air Quality Standards (NAAQS). http://www.epa.gov/air/criteria.html (accessed June 10, 2008).

U. S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Air Quality Assessment Division. *Latest Findings on National Air Quality, Status and Trends Through 2006*. Washington, D.C., 2008.

U. S. Environmental Protection Agency. Understanding the Clean Air Act. Brief History of the Clean Air Act. http://www.epa.gov/air/caa/peg/understand.html (accessed June 10, 2008).

Yanowitz, Frank G. "X. ST Segment Abnormalities." The Alan E. Lindsay ECG Learning Center in Cyberspace. http://library.med.utah.edu/kw/ecg/ecg_outline/Lesson10/index.html (accessed July 18, 2008).

Watson, Stephanie, ed. *Critical Perspectives on Pollution*. New York: The Rosen Publishing Group, Inc., 2007.