Outdoor air quality and health

Physicians can help protect and treat patients by understanding the connection

BY KRISTEN KELLOCK, PHD; EMILY ONELLO, MD; AND KRISTIN RAAB, MLA, MPH

PATIENT SCENARIO 1: *A Minnesota family physician notices a sudden increase in walk-in visits for asthma exacerbations. Could distant wildfires in the western United States be playing a role in this uptick of asthma activity?*

PATIENT SCENARIO 2: *A 56-year-old male patient returns to his primary care physician to discuss recent unexpected findings on his coronary angiogram. Atherosclerotic narrowing was noted and several stents were placed. The patient is puzzled because he lacks any of the classic risk factors for coronary artery disease. His physician wonders if past exposure to diesel exhaust and other air pollutants could have contributed to the patient's disease.*

Understanding Minnesota's air quality

Following the inception of the Clean Air Act in 1970 and amendments in 1977 and 1990, air quality has dramatically improved in the United States. The term "air quality" broadly describes either indoor or outdoor air in relation to potential adverse human health effects, visibility, odors or possible deterioration of man-made or natural structures from air exposure. Physicians are likely familiar with the acute health effects of impaired outdoor air quality but may not fully appreciate the more insidious chronic health impacts of outdoor air pollution. Understanding the adverse health effects of both acute and chronic exposure to air pollution helps physicians diagnosis and treat their patients.

The American Lung Association scores Minnesota's outdoor air quality good with respect to high ozone days and particle pollution, as well as in comparison to other states. For example, Minnesota counties (where monitoring data existed) scored As and Bs for high ozone days, which equates to 0–0.9 high ozone days from 2014 to 2016, while data for numerous California counties scored Ds and Fs for the same period.

FIGURE 1

Minnesota annual count of days in each Air Quality Index (AQI) category for ozone and fine particle matter 2.5 microns. Source: Minnesota Pollution Control Agency.

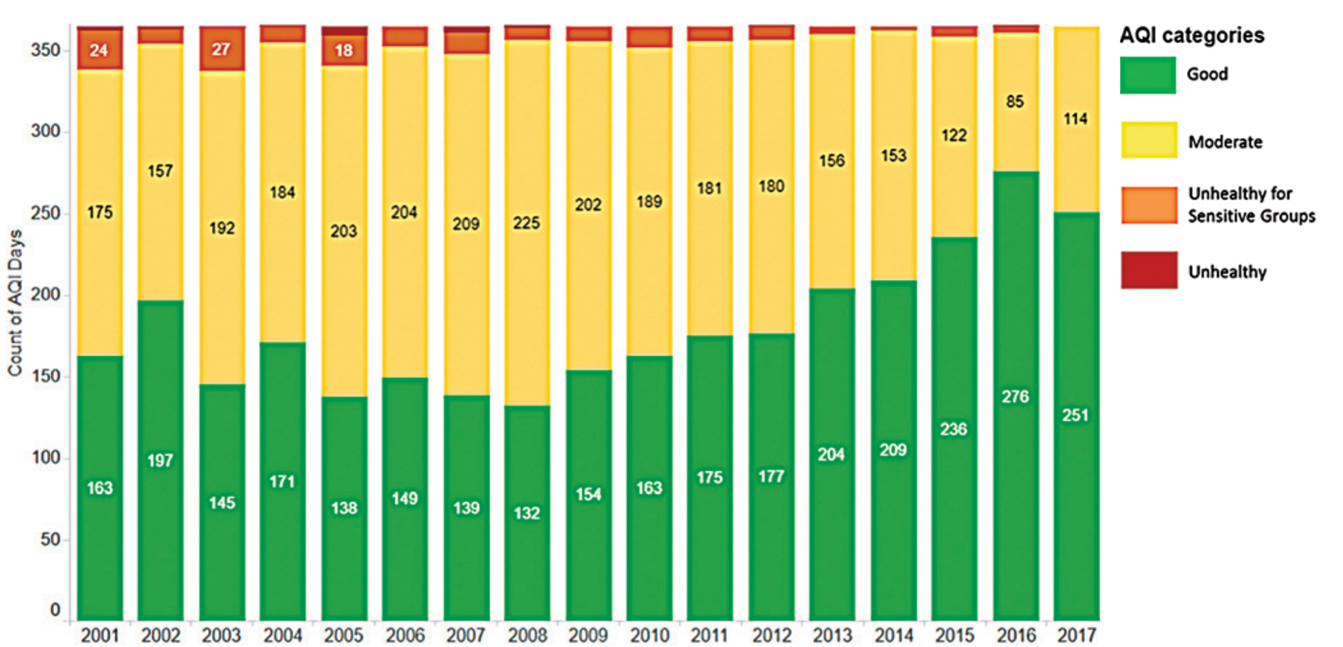
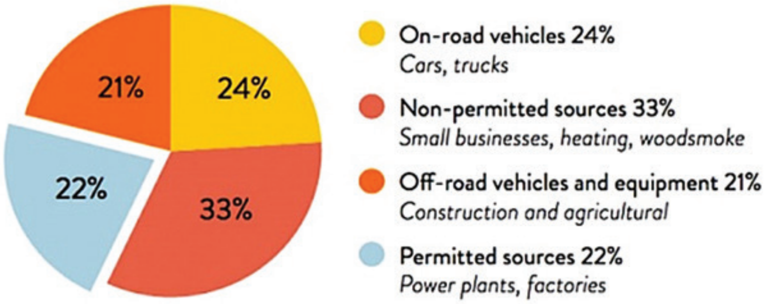


FIGURE 2

Air pollution emission sources in Minnesota from 2017.
Source: Minnesota Pollution Control Agency.



Even though Minnesota has overall better air quality than many states, areas of Minnesota still experience unhealthy air quality days throughout a year that can adversely affect human health (Figure 1). Medical professionals can help protect their patients and communities by understanding the drivers of air pollution, the potential acute and chronic health effects of poor air quality, the populations that are most sensitive to air pollution and the tools that can help prevent negative health impacts.

Air quality influences

Air pollutants are emitted from a wide range of sources. The pollution emissions in Minnesota generally come from what are known as permitted and non-permitted sources and on- and off-road vehicles, as defined by the Minnesota Pollution Control Agency (MPCA) (Figure 2). Permitted sources typically are large industrial facilities like power plants, factories and refineries. Non-permitted sources are generally smaller stationary sources of emissions that do not require an MPCA permit to emit. Gas stations, dry cleaners, residential wood combustion, prescribed burning and intentional or inadvertent agricultural burning are all examples of non-permitted sources. Mobile sources encompass vehicles, off-road and construction-related equipment powered by internal combustion engines, landscaping equipment, aircraft and trains. Local jurisdictions can require permits for MPCA's non-permitted sources, such as a city requiring a permit for backyard burning.

In addition to permitted and non-permitted pollution sources, other environmental factors can contribute substantially to air quality. Weather conditions, such as wind speed and direction, temperature, humidity and sunlight and presence of impediments (i.e., buildings, landscape topography) can influence air quality. For example, strong winds can carry pollutants long distances or disperse a pollutant, lowering concentrations near a source, but stagnant air and tall buildings can essentially trap pollutants, resulting in more unhealthy air quality days. In August 2018, wildfire smoke traveled from western Canada, prompting MPCA to issue an air quality alert for the entire state of Minnesota.

Air Quality Standards

The Clean Air Act requires the United States Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) for pollutants considered adverse to the public and environmental health. The NAAQS apply to six principal pollutants: particulate matter 2.5–10 microns in diameter, ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and lead. The NAAQS include primary and secondary standards. Primary standards provide health protection to populations that are particularly sensitive to air pollution. Secondary standards provide general public protection and consider factors such as compromised visibility and damage to animals, crops and buildings.

Of special interest for human health is particulate matter less than 2.5 microns in diameter (PM2.5). These particulates can be emitted directly from a source (i.e., wildfires or backyard burning) or can occur as the result of chemical reactions with sulfur dioxide and nitrogen dioxide, which are emitted from various industrial sources and automobiles. These smaller particles remain suspended in air longer than larger particles, thus lengthening the potential human exposure time. PM2.5 materials rival small bacteria in size, and are easily inhaled deep into human lungs. Scientific inquiry continues into the potential harms of PM2.5. A recent study suggested that the EPA's current standards for acceptable levels of exposure to PM2.5 (35 micrograms (µg)/cubic meter (m^3) per 24-hour averaging time or 12 µg /m^3 annual mean averaged over three years) could be more stringent to better protect public health. The study asserted that both acute and chronic health effects of PM2.5 exposure could be reduced by improving air quality even lower than the current U.S. EPA standards.

Acute health effects and vulnerable populations

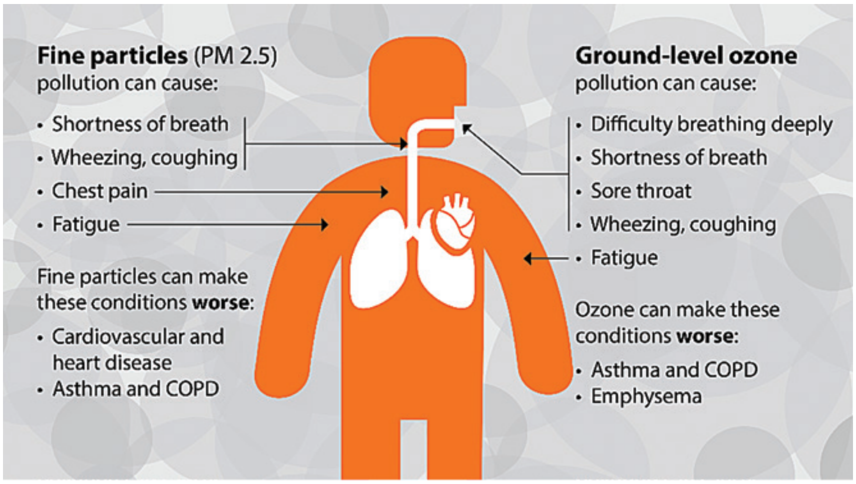
During a poor air quality event, people with existing respiratory conditions or those who are otherwise healthy may experience symptoms like difficulty breathing deeply, shortness of breath, throat soreness, wheezing, coughing or unusual fatigue (see Figure 3 for more detail). In **Patient Scenario 1**, a physician observes an increase in acute patient visits for asthma symptomatology during the community's exposure to air pollution from a wildfire. Acute adverse health events associated with air pollution are well documented and include a wide range of disorders, including cardiovascular events (angina, myocardial infarction, heart failure, abnormal heart rhythms), cerebrovascular events (strokes), asthma and COPD exacerbations.

The MPCA and the Minnesota Department of Health's (MDH) joint 2015 *Life and Breath Report* estimated that each year PM2.5 causes more than 2,100 deaths, more than 200 respiratory hospitalizations, 91 cardiovascular hospitalizations and about 400 emergency department (ED) visits for asthma in the Twin Cities. A 10 percent reduction in PM2.5 concentrations from 2008 baseline levels could prevent more than 200 deaths, more than 30 hospital admissions and more than 40 ED visits every year. Baseline ground-level ozone pollution is estimated to cause about 20 deaths, 47 hospitalizations for asthma and 185 ED visits for asthma. Ozone pollution causes an estimated 5 percent of all asthma hospitalizations and 3 percent of all asthma ED visits. A 10 percent reduction in ozone concentrations could prevent an estimated seven deaths, 14 hospital admissions and 57 ED visits in the Twin Cities. The MPCA and MDH are currently updating the *Life and Breath Report* to better understand and describe hospitalizations and ED visits attributable to air pollution in greater Minnesota.

FIGURE 3

Health effects associated with fine particle pollution and ozone.

Source: Minnesota Pollution Control Air Quality and Health.



People with preexisting respiratory ailments, like asthma, chronic obstructive pulmonary disease (COPD), cardiovascular disease or other related conditions, are more likely to be affected when ozone and/or particulate matter reach unhealthy levels. Young children, the elderly and people of all ages who are active outside are also at risk during poor air quality days. In 2016, MDH reported that the asthma hospitalization rate for children living in the Twin Cities-metro area was 67 percent higher than for children living in Greater Minnesota. Patient education on air pollution and health, especially among urban and sensitive populations, may help to minimize emergency medical care.

Chronic Health Effects

Air pollution can also cause chronic health effects through similar pathophysiologic mechanisms as tobacco smoke. Physicians easily conceptualize the deleterious health effects of tobacco smoking. Cigarette smoke passes through the lining of the respiratory tree, the lung alveoli, the vascular interface and spreads systemically as toxins are absorbed into general circulation. Yet during patient care encounters, physicians may not routinely consider the harms of air pollution. The 56-year-old patient in **Patient Scenario 2** has developed atherosclerotic coronary artery disease in the absence of recognized risk factors, but he had experienced chronic exposure to ambient levels of outdoor air pollutants, which may have played a role in disease development.

Mechanistically, air pollution's combustion-driven nanoparticles are inhaled and result in pulmonary inflammation and subsequent translocation from the lung into the systemic circulation with subsequent direct cardiovascular effects. Pro-inflammatory pathways are activated and tissues experience cellular oxidative stress. Particulate matter augments the development and progression of atherosclerosis via detrimental effects on platelets, vascular tissue and the myocardium. Current modeling extends the pathologic impact of particulate matter inhalation to include amplified systemic inflammatory and oxidative stress responses, induced autonomic nervous system imbalances and increased thrombosis risk.

Atherosclerosis, coronary and cerebrovascular concerns

Given that air pollution and tobacco smoke are similar in pathophysiologic mechanisms, it is not a surprise that exposure to air pollution has been associated with an increase in stroke and heart attack, as well as other cardiovascular events, such as abnormal cardiac rhythms and congestive heart failure. Studies have shown that PM2.5 exposure can result in vasoconstriction and impaired endothelial function. A 2015 publication from the Multi-Ethnic Study of Atherosclerosis (MESA) and Air Pollution revealed that both short- and long-term exposure to ambient PM2.5 levels were independently related to reductions in retinal arteriole diameter. In a subsequent 2016 report, the MESA Air study revealed that long-term exposure to PM2.5 at ambient urban levels of six metropolitan areas in the United States showed a significant increase in coronary artery calcification. Compounding the effects, epidemiologic studies provide some evidence that PM2.5 air pollution may contribute to the development of cardio-metabolic conditions. There is good evidence that exposure to outdoor air pollution should be included among the important modifiable risk factors for cardiovascular disease (smoking, diabetes, high cholesterol, hypertension, sedentary lifestyle).

Pulmonary and other effects

Chronic exposure to air pollutants has been shown to increase risk of lung cancer and can make asthma worse. Air pollution has also been linked to a variety of other conditions, including preg-

Useful links for further information

+ **Air Now Guide to Air Quality and Your Health.** www.airnow.gov/index.cfm?action=aqi_brochure.index
+ **EPA air quality research areas.** www.epa.gov/air-research

EPA Air Quality and Climate Change research

+ **EPA's History of the Clean Air Act.** www.epa.gov/clean-air-act-overview
+ **MDH Asthma Program.** www.health.state.mn.us/diseases/asthma/about/whoweare.html
+ **MDH Cardiovascular Health Unit.** https://www.health.state.mn.us/diseases/cardiovascular/cvhunit/
+ **MDH Minnesota Public Health Data Access Portal.** https://data.web.health.state.mn.us/web/mndata
+ **MPCA emissions source categories.** www.pca.state.mn.us/air/sources-air-pollution
+ **MPCA reports on NAAQS.** www.pca.state.mn.us/air/current-condition-details

nancy-related disorders, neurological disorders, rheumatologic and mental health conditions. The systemic inflammatory events that occur in response to air pollution exposure affect diverse organs, suggesting that exposure to air pollution should be considered when reviewing a patient's medical history.

Health protection tool

The EPA developed the Air Quality Index (AQI) to provide a homogenous way to report on daily air quality conditions incorporating the NAAQS pollutants previously mentioned. The MPCA created a Minnesota-specific AQI tool to report on air quality, based on hourly measurements from approximately 30 individual monitoring sites throughout the state. Through the use of monitor data, artificial intelligence, automated weather predictions and in-house meteorological expertise, MPCA now forecasts air quality conditions for 18 locations across the state and releases customized AQI Alerts for anywhere in Minnesota.

The categories of air quality (Figure 4) are easy to understand and are accompanied with a corresponding color to denote the level of potential health impact. Green indicates clean air that is safe for everyone, and progressively warmer colors indicate higher levels of pollution and levels of health concern, as seen in Figure 4. Patients can track the daily AQI on MPCA's website (www.pca.state.mn.us/air/current-air-quality) or by downloading the MN Air Mobile App through Android, Apple or Windows app stores. Providing patients information on how to track and interpret the MPCA's AQI could help them better prepare for poor air quality days and implement strategies to protect their health.

While some individuals may be affected by air pollution more than others, everyone should take precautions when the air quality is unhealthy. On air quality alert days, it is advised that people avoid strenuous outdoor activity and stay away from local sources of air pollution, like busy roads and wood fires. People with breathing problems should also have their relief/rescue inhaler with them.

Patients may have questions about the value of commercially available, sometimes costly, indoor air filters or personal/wearable air purifiers.A recent study of senior citizens in Detroit demonstrated significant reduction in PM2.5 exposure using commercially available portable air filters, but the long-term health benefits of such devices have not been adequately studied. In some

FIGURE 4

Minnesota Pollution Control Agency's Air Quality Index (AQI) categories. Each color represents an AQI range and corresponding level of human health concern.

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*..air quality conditions are:*	*...as symbolized by this color:*
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

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circumstances, N95 (filters at least 95 percent of airborne particles) and N99 (filters at least 99 percent of airborne particles) National Institute for Occupational Safety and Health-approved particulate-filtering face-piece respirators can filter out PM pollution of 0.1–0.3 µm and larger (but are not effective against ozone and other gases such SO2). These devices may be options for vulnerable patients during known exposures, such as smoke from wildfires, but need to be fitted correctly to be health-protective. Discussing these strategies can help patients find ways to stay healthy on poor air quality days.

Summary

Physicians and state agencies can work together to improve Minnesota's air quality and protect the health of Minnesota's citizens. While air quality throughout Minnesota generally meets EPA's NAAQS and there are fewer unhealthy air days compared to other states, those who are sensitive to air pollution know it only takes one day with unhealthy air to feel an impact. Air pollution is associated with acute as well as chronic health effects, including stroke, heart attack, other cardiovascular events and cardio-metabolic conditions and cancer. The new MPCA AQI forecasting program puts Minnesota ahead of the curve by providing easy to understand air quality and health information at our fingertips. Patients and their physicians can use this program to educate themselves and their communities to reduce exposure to unhealthy air and protect their health. Exposure to outdoor air pollution is a modifiable risk factor for cardiovascular and other diseases. MM

Kristen Kellock, PhD, is a research scientist in the Environmental Impacts Analysis Unit of the Minnesota Department of Health. Emily Onello, MD, is assistant professor in the Department of Family Medicine and Biobehavioral Health at the University of Minnesota Medical School-

Extreme heat

Who's at highest risk?

This project is a collaboration of the Minnesota Department of Health and Wisconsin Department of Health Services. Lead investigators were Tess Konen, MPH, Minnesota Department of Health, and Paul D. Cresswell, PhD, Wisconsin Department of Health Services.

Extreme heat events in Minnesota and Wisconsin are already occurring and are expected to become more common, more severe, and longer lasting as our climate changes. Extreme heat causes entirely preventable illness and death.

For years, staff in the Minnesota and Wisconsin Environmental Public Health Tracking programs used similar messaging about how older adults, infants and people with chronic health conditions—particularly in urban areas—were more likely to suffer from heat-related illness. Anecdotally, our programs started noticing more cases of heat-related illness outside of these populations.

Our states teamed up to build a more robust dataset to better understand who is most impacted by extreme heat. Because Minnesota and Wisconsin have similar climates, populations and patterns of heat-related illness, we decided to combine our data and work together to assess current trends and patterns.

What we did

In 2017, our state Environmental Public Health Tracking programs began discussing heat-related illness and how to frame an analysis. We decided to base the analysis on the following data:

Emergency department data. Any Minnesota or Wisconsin resident who went to the emergency department for heat-related illness during warm weather months (May-September) 2006–2015 was included in the analysis. Veteran's Administration and Indian Health Services hospitals were not included in the analysis.

Risk factor data. Staff pulled data on known risk factors for heat-related illness, such as being an older adult or living in poverty. In total, we assessed 17 county-level variables linked to heat-related illness.

HEAT-RELATED ILLNESS EMERGENCY DEPARTMENT VISITS

Minnesota and Wisconsin by County, 2006-2015