Health effects of outdoor air pollution

Approach to counseling patients using the Air Quality Health Index

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Abstract

Objective To inform family physicians about the health effects of air pollution and to provide an approach to counseling vulnerable patients in order to reduce exposure.

Sources of information MEDLINE was searched using terms relevant to air pollution and its adverse effects. We reviewed English-language articles published from January 2008 to December 2009. Most studies provided level II evidence.

Main message Outdoor air pollution causes substantial morbidity and mortality in Canada. It can affect both the respiratory system (exacerbating asthma and chronic obstructive pulmonary disease) and the cardiovascular system (triggering arrhythmias, cardiac failure, and stroke). The Air Quality Health Index (AQHI) is a new communication tool developed by Health Canada and Environment Canada that indicates the level of health risk from air pollution on a scale of 1 to 10. The AQHI is widely reported in the media, and the tool might be of use to family physicians in counseling high-risk patients (such as those with asthma, chronic obstructive pulmonary disease, or cardiac failure) to reduce exposure to outdoor air pollution.

Conclusion Family physicians can use the AQHI and its health messages to teach patients with asthma and other high-risk patients how to reduce health risks from air pollution.

Résumé

Objectif Faire connaître aux médecins de famille les effets de la pollution atmosphérique sur la santé et indiquer quels conseils donner aux patients vulnérables pour qu'ils soient moins exposés.

Sources de l'information On a consulté MEDLINE à l'aide des termes relatifs à la pollution atmosphérique et à ses effets indésirables. On a révisé les articles en anglais publiés entre janvier 2008 et décembre 2009. La plupart des études contenaient des preuves de niveau II.

Principal message Au Canada, la pollution de l'air extérieur cause une morbidité et une mortalité importantes. Elle peut affecter le système respiratoire (exacerbation de l'asthme et de la maladie pulmonaire obstructive chronique) et le système cardiovasculaire (déclencher l'arythmie, l'insuffisance cardiaque et les AVC). La cote air santé (CAS) est un nouvel outil de communication mis au point par Santé Canada et Environnement Canada qui indique sur une échelle de 1 à 10, le risque pour la santé causé par la pollution atmosphérique. La CAS est largement diffusée dans les médias et cet outil pourrait être utile au médecin de famille pour inciter les patients à haut risque (comme ceux qui souffrent d'asthme, de maladie pulmonaire obstructive chronique ou d'insuffisance cardiaque) à réduire leur exposition à la pollution atmosphérique.

KEY POINTS Exposure to outdoor air pollution has a substantial effect on health, including exacerbation of pre-existing asthma and chronic obstructive pulmonary disorder, increased susceptibility to infection and sensitivity to allergens, and increased risk of arrhythmia, ischemia, cardiac failure, and stroke. Patients with pre-existing conditions, children, and seniors are particularly at risk. Combustion of fossil fuels for transportation, home heating and cooling, and industry are the main sources of air pollution. Reducing exposure, especially from traffic, is the most effective strategy to mitigate the effects of pollution. The Air Quality Health Index is a tool that can help patients gauge risk before engaging in outdoor activity.

POINTS DE REPÈRE L'exposition à court ou à long terme à la pollution atmosphérique a des effets importants sur la santé, y compris l'exacerbation de l'asthme ou d'une maladie pulmonaire obstructive chronique préexistante, l'augmentation de la susceptibilité aux infections et de la sensibilité aux allergènes, ainsi qu'un risque accru d'arythmie, d'ischémie, d'insuffisance cardiaque et d'AVC. Les patients plus à risque sont ceux qui souffrent déjà d'une affection, de même que les enfants et les personnes âgées. L'utilisation de combustibles fossiles pour le transport, le chauffage ou la climatisation des maisons et les activités industrielles représentent les principales sources de pollution de l'air. Réduire l'exposition, surtout à la pollution due à la circulation, constitue la stratégie la plus efficace pour en atténuer les effets. La cote air santé est un outil qui peut aider les patients à évaluer leur risque avant d'entreprendre une activité en plein air.

This article has been peer reviewed.
Can Fam Physician 2011;57:881-7

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Conclusion Le médecin de famille peut se servir de la CAS et de ses messages sur la santé pour enseigner aux asthmatiques et aux autres patients à risque élevé la façon de réduire les risques pour la santé causés par la pollution atmosphérique.

Case description

Mrs Smith calls you about her 11-year-old daughter, Judy, who has asthma that is difficult to control. Mrs Smith has heard on the news that the Air Quality Health Index (AQHI) is forecast to be 7 the next day, and Judy is scheduled to compete in an all-day athletics event. She is concerned that Judy's asthma might be aggravated by the air pollution during a full day outdoors. She asks your advice as to whether Judy should attend the event.

What is your assessment of the risk to your patient and your subsequent advice to her mother?

Sources of information

In preparing this article, MEDLINE was searched using terms relevant to air pollution and adverse effects in general, as well as *ozone, particulate matter, nitrogen dioxide,* and *traffic-related air pollution.* We reviewed English-language articles published between January 2008 and December 2009, yielding 462 (117 relevant) articles and 66 (17 relevant) reviews. Articles related to tobacco smoke, indoor air, and occupational exposures were removed. Relevant articles published before 2008 were identified by searching the reference lists of studies found during the primary search.

Burden of illness from air pollution

Outdoor (ambient) air pollution has a substantial influence on the health of Canadians. Both short-term and long-term exposure to air pollution affect the respiratory and cardiovascular systems. Recent research has highlighted the extent of the effects of air pollution on the cardiovascular system, the complex mechanisms of these effects, and the fact that adverse health effects occur at low pollution levels, similar to those of the air that Canadians in many parts of the country breathe. In this article we discuss the epidemiologic and toxicologic evidence for these health effects and the burden of disease in Canada. We also discuss what family physicians can do to help their patients and introduce a new tool, the AQHI. The AQHI can be used to counsel patients in the family practice setting, especially those at high risk (patients with asthma, chronic obstructive pulmonary disease [COPD], cardiovascular disease, and diabetes, as well as seniors and children), to help them monitor their response to air pollution and reduce harmful exposure.

There is a meaningful burden of illness from air pollution, but because air pollution is "upstream" and cannot be measured in the individual patient, much like hypertension, it is usually not apparent as a causative agent in clinical practice. In 2004, Health Canada estimated that air pollution caused nearly 6000 premature deaths in 8 cities in Canada each year, which accounted for approximately 8% of deaths from all causes in the study population. Long-term exposure accounted for more than 70% of these deaths.[1] The Canadian Medical Association recently extended this analysis to the entire country and estimated that approximately 21 000 deaths from all causes (excluding accidents and violence) could be attributed to air pollution in 2008 (approximately 10% owing to short-term exposure), together with 11 000 cardiac- and respiratory-related hospital admissions and 92 000 emergency department visits. National economic damages (including lost productivity, health care costs, pain and suffering, and loss of life) have been estimated to be $8 billion.[2]

Health effects of air pollution

An extensive body of evidence links exposure to outdoor air pollution and health effects. Evidence is derived from epidemiologic studies (mostly time series studies and cohort studies), toxicologic studies of animals, and controlled human exposure studies (chamber studies); therefore, most studies provide level 2 evidence. The health effects considered are measured by short-term exposure to pollutants of hours, days, or weeks and long-term exposure of months or years (**Table 1**[3-43]).

The effects of short-term exposure include exacerbation of pre-existing respiratory disease (especially asthma and COPD) and pre-existing cardiovascular disease (including ischemia, arrhythmias, and cardiac failure), with increased hospitalization and emergency department visits. Long-term exposure to air pollution is associated with increased mortality, increased incidence of lung cancer and pneumonia, and development of atherosclerosis.

Although it was previously understood that air pollution led only to exacerbation of asthma, there is now evidence from cohort studies that long-term exposure to air pollution might lead to development of new asthma and might delay development of the lungs.

The health effects of traffic-related air pollution, comprising a mixture of pollutants, is an area of recent research interest.[30] A study in Toronto, Ont, showed that exposure to traffic-related air pollution at time of birth was associated with increased current asthma in school-aged children.[39] Wood smoke, a common air pollutant in Canada from forest fires and residential wood burning for heating, is also associated with negative health effects.[44]

Mechanisms of action of air pollution

Individuals vary in their response to different air pollutants. Some genetic polymorphisms contribute to increased susceptibility.[45-47] At the population level, it is believed that

Table 1. Health effects of air pollution

EXPOSURE	SYSTEM AFFECTED	HEALTH EFFECTS	STUDY
Short term	Cardiovascular	Increased rates of myocardial infarction and ischemia in those at risk	Bhaskaran et al,[3] 2009 Pope et al,[4] 2006 Szyszkowicz,[5] 2009 Brook et al,[6] 2010
		Exacerbation of cardiac failure	Brook,[7] 2008 Goldberg et al,[8] 2009 Medina-Ramón et al,[9] 2008 Pope et al,[10] 2008
		Increased incidence of arrhythmia	Pope et al,[11] 2004
		Increased incidence of deep vein thrombosis	Pope,[12] 2009 Baccarelli et al,[13] 2009
		Increased incidence of stroke	Lokken et al,[14] 2009
	Respiratory	Increased wheeze	Clark et al,[15] 2010
		Exacerbation of asthma	Delfino et al,[16] 2009 Holguin,[17] 2008 O'Connor et al,[18] 2008 McCreanor et al,[19] 2007
		Exacerbation of chronic obstructive pulmonary disease	Halonen et al,[20] 2008 Sint et al,[21] 2008 Zanobetti et al,[22] 2008
		Bronchiolitis and other respiratory infections	Karr et al,[23] 2009 Ségala et al,[24] 2008
		Increased emergency department visits	Stieb et al,[25] 2009
Long term	General	Increased mortality	Krewski et al,[26] 2009 Pope et al,[27] 2009
	Cardiovascular	Increased myocardial infarction	Rosenlund et al,[28] 2009 Tonne et al,[29] 2009
		Accelerated development of atherosclerosis	Brook et al,[6] 2010 HEI Panel on the Health Effects of Traffic-Related Air Pollution,[30] 2010
		Increased blood coagulability	Pope,[12] 2009 Liu et al,[31] 2009
		Increase in systemic inflammatory markers	Simkhovich et al,[32] 2008
	Respiratory	Increased incidence of pneumonia	Neupane et al,[33] 2010
		Increased incidence of lung cancer	Laden et al,[34] 2006
		Impaired lung development in children	Gauderman et al,[35] 2004
		Development of new asthma	Clark et al,[15] 2010 Jerrett et al,[36] 2008 Künzli et al,[37] 2009 Lindgren et al,[38] 2009 Dell et al,[39] 2008
	Reproductive	Increased incidence of preterm birth	Wu et al,[40] 2009 Stillerman et al,[41] 2008 Brauer et al,[42] 2008
		Increased incidence of low birth weight	Salam,[43] 2008

there is no threshold for the health effects of air pollution, so that even the relatively low levels of pollution commonly found in Canada have implications for health.

Effects on the respiratory system include pulmonary inflammation, airway obstruction, and increased susceptibility to infection and sensitivity to allergens. Cardiovascular effects associated with short-term exposure include changes in heart rate variability, blood pressure, vascular tone, and blood coagulability, while long-term exposure might accelerate the progression of atherosclerosis. Many of these effects are mediated through proinflammatory pathways and the generation of reactive oxygen species.[6,48]

Sources of air pollution

Air pollutants are usually present in the air as a mixture, or "soup," of constituent gases and particles. The main pollutants and their sources are shown in **Table 2.** In general, combustion of fossil fuels for transportation, home heating and cooling, and industry are the main sources of air pollution. Pollution can be regional when large geographic areas are covered by pollution (for example, the smog [mostly ozone and particulate matter] in the Quebec City–Windsor corridor, the Fraser River Basin, and southern Atlantic Canada) or local, such as pollution from traffic, local industries, or wood smoke. Motor vehicle emissions consist mostly of carbon monoxide, nitrogen oxides, volatile organic compounds, and particulate matter (PM); levels are elevated close to busy roads, but fall off rapidly within 150 m of the road. The most common pollutants, listed in **Table 2,** are widely monitored.

Ground-level ozone, a colourless and odourless gas, causes inflammation of the airways. Particulate matter is classified according to size. Size is important, as smaller particles with diameters of less than 2.5 µm (PM 2.5) penetrate deeper into the lungs, reaching and affecting the alveoli, while larger particles with diameters from 2.5 to 10 µm (PM 10) are filtered out at higher levels in the airways. The smallest particles, ultrafine particles with diameters of less than 0.1 µm, can cross the alveolar membrane into the bloodstream. The chemical properties of particles are complex, varying according to their sources, and also play a part in the effects on health. Some population groups are more vulnerable than others to the effects of air pollution (**Table 3**[49]).

Air Quality Health Index

Family physicians can counsel patients to reduce exposure to air pollution so as to reduce the amount of pollutant delivered to their lungs and other organs. Short-term reduction of exposure can be achieved by modifying activities in relation to reports of air quality conditions.

The AQHI is a new health risk communication tool that indicates the level of risk from short-term exposure to air pollution. The values are derived from monitoring the 3 pollutants (ozone, PM, and nitrogen oxides) that best

Table 3. Groups vulnerable to the effects of air pollution

FACTOR	VULNERABLE GROUP
Age	Children, who spend more time outdoors, are more physically active, inhale more air per kilogram of body weight, and whose developing lungs are more vulnerable to damage
	Seniors
Pre-existing disease or condition	Patients with asthma, COPD, cardiovascular disease, ASHD, CCF, or diabetes[49]
	Patients who are pregnant
Increased exposure	People exercising outdoors
	Outdoor workers

ASHD—arteriosclerotic heart disease, CCF—congestive cardiac failure, COPD—chronic obstructive pulmonary disease.

Table 2. Sources of air pollution

POLLUTANT	SOURCE	CONDITIONS
Particulate matter	Traffic Forest fires Wood smoke Infiltrates indoors	Summer and winter
Ultrafine particulate matter (<0.1 µm in diameter)	Diesel traffic	Close to busy roads
Ozone	Secondary to aerochemical reaction to nitrogen oxides and volatile organic compounds	Summer afternoons; heat and sunshine
Nitrogen dioxide	Traffic	Close to busy roads
Carbon monoxide	Traffic	Close to busy roads
Sulfur dioxide	Industrial plants—combustion and refining of coal, oil, and metal-containing ores	Close to industrial sources
	Gasoline, although sulfur content has recently been reduced	

Table 4. The AQHI categories and messages

		HEALTH MESSAGES	
HEALTH RISK	AQHI CATEGORY	AT-RISK POPULATION*	GENERAL POPULATION
Low	1 to 3	**Enjoy** your usual outdoor activities	**Ideal** air quality for outdoor activities
Moderate	4 to 6	**Consider** reducing or rescheduling strenuous outdoor activities if you are experiencing symptoms	**No need to modify** your usual outdoor activities unless you experience symptoms of coughing and throat irritation
High	7 to 10	**Reduce** or reschedule strenuous outdoor activities. Children and the elderly should also take it easy	**Consider reducing** or rescheduling strenuous outdoor activities if you experience symptoms of coughing and throat irritation
Very high	Above 10	**Avoid** strenuous outdoor activities. Children and the elderly should avoid outdoor physical exertion	**Reduce** or reschedule strenuous outdoor activities, especially if you experience symptoms of coughing and throat irritation

AQHI—Air Quality Health Index.

*People with heart or breathing problems are at greater risk. Follow your doctor's usual advice about exercising and managing your condition.

Data from Environment Canada.[51] This table is adapted from an official work published by the Government of Canada; this adaptation has not been produced in affiliation with or with the endorsement of the Government of Canada.

represented health risk in a succession of epidemiologic time series studies conducted in Canada.[50] The AQHI has been developed by Health Canada and Environment Canada, in conjunction with a number of other partners, and is currently being rolled out across the country.

The AQHI replaces existing Air Quality Indices, with which there were several problems. The Air Quality Indices were based on a threshold below which the air quality was reported as "good," frequently ignoring the health effects on high-risk people at low pollutant concentrations; their reports were based only on the worst offending pollutant at any given time, rather than the mix of pollutants that we are exposed to; they did not have well-developed health messages; and they were inconsistent in provinces across the country.

Conversely, the AQHI indicates the current and next day's health risk from air pollution in a coloured scale from 1 to 10; advises how to assess vulnerability to the effects of air pollution based on known risk factors, defining at-risk groups (**Table 3**[49]); suggests that individuals self-calibrate, learning their sensitivity to each risk level of the AQHI; and delivers a protective health message to reduce exposure, advising a reduction of strenuous outdoor activities (as exercise increases respiratory minute ventilation) according to AQHI risk level and risk group (**Table 4**[51]). An example of an AQHI forecast from June 28, 2011, is provided in **Figure 1.***

The AQHI scale can easily be taught to at-risk patients, for example, in an asthma action plan or in asthma education. Clinical advice of this kind is recommended in clinical practice guidelines for management of asthma, respiratory disease, and cardiac disease.[6,52,53] Although the project is still being rolled out, the AQHI is available to most patients nationally through the Weather Network and in many areas through local newspapers and weather reports. The AQHI can also be accessed via "push technology" or social media platforms, such as Twitter or widgets. Using this technology, at-risk patients no longer have to seek out the AQHI but instead can register through the Canadian Lung Association or the Asthma Society of Canada to receive daily AQHI updates. In addition to the daily AQHI, many communities also have air quality or smog advisories to advise the population when air pollution reaches a predetermined level of concern. **Figures 2*** and **3*** are tear sheets that we have found useful for FPs to use with their patients.

Although there is no direct experimental evidence to support the effectiveness of air quality index or advisory programs, there is indirect evidence that supports the expectation of short-term health benefits. A recent epidemiologic study in Ontario has shown that each unit increase of daily AQHI values is associated with a substantial increase in emergency and outpatient department visits for asthma, up to 2 days later.[54] Wen and colleagues showed that awareness of air pollution media alerts and health professional advice might change behaviour,[55] while Stieb et al have shown that following smog advisory advice reduces exposure to outdoor air pollution (although potentially increasing exposure to indoor source pollutants).[56] McCreanor et al demonstrated that exercising away from traffic mitigated short-term lung inflammation and reductions in lung function in patients with asthma.[19] A pilot study to examine the applicability and effectiveness of the AQHI in patients with asthma is under way, and further studies are recommended. Air quality index and advisory programs that advise reducing physical activity might conflict with broader recommendations promoting physical activity[57]; the benefits and risks must be appropriately balanced on a case-by-case basis.

*Figures 1 to 3 are available at www.cfp.ca. Go to the full text of this article online, then click on CFPlus in the menu at the top right-hand side of the page.

Other interventions to protect patients from air pollution

As the greatest burden of disease related to air pollution is associated with long-term exposure, interventions that separate people from sources of pollutants over the long term are likely to be associated with the greatest health benefit. As an example, California's school siting bill (SB 352) mandates that no new schools be built within 500 feet of a highway and prohibits school buses from idling near schools.[58,59] Similar recommendations have been made with respect to siting of day-care centres,[60,61] hospitals, and long-term care facilities.[62] The same rationale might also be used to support advising people to avoid areas of higher air pollution, such as those with heavy traffic and increased industrial emissions.[56]

Ultimately, the most effective intervention is primary prevention—the reduction in emissions of air pollutants. Active commuting (eg, biking, walking) reduces air pollution (and greenhouse gas emissions) and supports a more active lifestyle, which also has important health benefits.

Disease control is also important. Better asthma control, especially with anti-inflammatory medications, is a protective measure against the effects of air pollution.[63] Acute exacerbations of chronic cardiac or respiratory conditions triggered by air pollution should be managed clinically in the same manner as exacerbations triggered by other factors.

Case resolution

The forecast for the next day, when Judy's athletics event is planned, calls for an AQHI of 7, indicating a high health risk from air pollution. Patients with ashthma are considered an at-risk group. Judy would be outdoors and exposed to air pollution for a long time, and her exposure would be further increased when running, as cardiovascular activity amplifies minute ventilation. The health message at an AQHI of 7 advises at-risk groups to "reduce or reschedule strenuous outdoor activities" (**Table 4**[51]). However, the AQHI also encourages patients to "self-calibrate"—to determine their sensitivity to the effects of air pollution on their health. If Judy has self-calibrated, she would have a better idea as to what effect an AQHI of 7 would have on her asthma. Also, better asthma control, especially with anti-inflammatory medication, is protective. Depending on what she knows about her response to air pollution from her self-calibration results, Judy might be advised to not participate and to stay indoors, or if she does participate, to optimize her controller medication and have her rescue medication with her.

Someone with COPD, cardiac failure, angina, or an arrhythmia, or a healthy person going for a run, would be advised to check AQHI levels and health messages daily and plan accordingly. With a high-risk AQHI of 7, the at-risk patient should be advised to stay indoors and the runner, although healthy and not at risk from any pre-existing disease, would be advised to reduce exposure by running at a lower intensity or a shorter distance and not running near heavy traffic. Some at-risk and healthy patients will find at self-calibration that they are sensitive to moderate-risk AQHI levels of 4, 5, or 6.

Conclusion

The AQHI in general encourages exercise in accordance with other public health guidelines except in situations of higher risk from air pollution, which occur infrequently. In those situations, people are advised to reduce strenuous outdoor activity, to move indoors, or to reschedule. They are also advised to avoid cumulative exposures by not exercising near traffic and to be aware of the risks of exercising in excessive heat.

The AQHI is a public health and clinical tool that can easily be taught to vulnerable patients, such as patients with asthma, COPD, and cardiovascular disease, by family physicians and other health professionals. Family physicians can learn more about the health effects of air pollution and about the AQHI through accredited online courses and educational brochures.[64,65]

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Contributors

Both authors contributed to the literature review and preparing the article for submission.

Competing interests

Both authors work at Health Canada, in the Healthy Environments and Consumer Safety Branch. Health Canada has developed and is promoting the new Air Quality Health Index.

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