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Perspective

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Every breath you take: how does air pollution affect the international traveller?

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Travel involves a complex interaction between the traveller, the process of travelling, and the final destination. In 2014, 92% of the world's population was living in regions that did not meet the World Health Organization (WHO) air quality guidelines, with 88% of air pollution-related premature deaths occurring in low and middle income countries.[1] It is reasonable to suggest that the ambient air quality of travel destinations may influence both the acute and chronic state of health of the traveller. According to the USA's Environmental Protection Agency, there are six fundamental air pollutants: ground-level ozone, particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and lead.[2] In combination, these pollutants pose risks to the traveller's health, and they may contribute to the worsening of pre-existing medical conditions.

To better understand the risk that these pollutants present to the traveller, it is important to understand their origin. Based on their source of production, air pollutants can be divided into two categories: primary and secondary air pollution. Primary air pollutants are directly emitted into the atmosphere, often from combustive sources, yielding compounds such as SO_2, NO_2 and CO. Secondary air pollutants are those that are produced as a result of the reaction between primary pollutants and the elements of the atmospheric environment, such as sunlight and moisture, producing compounds such as O_3.[2] Particulate matter (PM) is composed of both solid and liquid particles, and arises from both primary sources (e.g. mechanical disruption, incomplete combustion, naturally arising pollen, spores, ash) and secondary sources (e.g. gas-to-particle conversion, vapour condensation, or chemical reactions at the surface of primary aerosol particles). Airborne exposure to lead is of limited risk to the traveller, due to the United Nations Environment Programme's successful campaign to eliminate lead petrol usage; lead petrol is currently used in only six countries (Afghanistan, Algeria, Iraq, Myanmar, North Korea and Yemen), all of which have suffered civil strife in recent times and none of which is a popular tourist destination currently.

PM_{10} (<10 μm) is composed of both fine and coarse particles, and $PM_{2.5}$ (<2.5 μm) is composed of fine particles. $PM_{2.5}$ is of particular relevance, as its smaller size permits entry into the smaller terminal airways, leading to a greater respiratory disease risk.[3–5] Current WHO guidelines suggest annual mean concentrations of 10 μg/m^3 for $PM_{2.5}$ and 20 μg/m^3 for PM_{10}.[1] The World Health Organization publishes online interactive maps which display the annual mean ambient concentrations of $PM_{2.5}$ in Africa, Central Europe and Asia, the most recent map representing 2016, and showing widespread exceedance of the guideline annual mean concentrations.[6] The 2016 map includes 3000 more cities than the 2014 map, but it should be noted that the vast majority of ground-based monitors on which the data are based are located in developed cities. Data for developing cities, which are least equipped to monitor their ambient environment and to consider seasonal and diurnal air pollution trends, can be considered only as representative. These maps are published with a disclaimer which states that their estimates are subject to considerable uncertainty, especially for countries with weaker statistical information protocols.

Urban residents with conditions such as chronic obstructive pulmonary disease (COPD),[5] coronary heart disease, asthma[3] and blepharitis[7], for example, may experience symptom exacerbations as a result of ambient air pollution. Sanford, in his comprehensive review of health risks facing residents in urban areas in developing countries, asserts that it is likely that travellers are also subject to these risks, although the nature and magnitude of the health risk have yet to be established.[8] Gordon and Reibman[9] have usefully tabulated the strength of the evidential links between inhaled ambient PM and adverse cardiovascular

effects. Increased exposure to ozone and PM has been linked to increased hospital admissions and mortality rates for individuals with respiratory and cardiopulmonary diseases, but no threshold values for adverse health effects have been reported.[10] PM, in particular, has been shown to increase the serum concentration of fibrinogen and platelets, with sequestration of red blood cells in the lungs.[11] The potentially pro-arrhythmogenic effect of $PM_{2.5}$ is supported by an Italian study,[12] but further research is indicated before causality can be determined. A study conducted by Malerbi *et al.*[7] in Sao Paolo, Brazil, analysed the influence of ambient air pollution exposure on the development or exacerbation of blepharitis. They found that exposure to all air pollutants, and more specifically NO_2, correlated with increased eyelid debris and Meibomian gland secretion, which are both markers of blepharitis.[7]

Travellers with respiratory conditions such as COPD and asthma are especially prone to symptom exacerbations, due to the increased airway inflammation provoked by exposure to pollutant antigens. Inhalation of particulate matter and other combustive pollutants may exacerbate the symptoms of cardiac and respiratory diseases, including dyspnoea and cough, and further compromise pulmonary function.[3–5] Long-term travellers are at greatest risk and require counselling about how to self-manage exacerbations and access local medical care overseas (Table 1). Sanford advocates the use of anti-inflammatory medications, such as montelukast sodium, in children with asthma prior to and during their stay in cities with high levels of air pollution.[8]

Alongside the dangers of exposure to air pollutants, it is important to observe the effects that temperature and humidity exert on the traveller, especially when accompanied by high levels of air pollution. Studies have demonstrated that exposure to higher temperatures is associated with COPD and asthma symptom exacerbations.[13,14] Research conducted in New York City showed that the risk of COPD-related hospitalizations increased by 7.6% for every 1°C increase above a cut-off temperature of 29°C.[14] Shaposhnikov *et al.*[15] analysed the number of deaths associated with the heat wave and wild fire period during the summer months of 2010, in Moscow. The team analysed the temperatures, as well as PM_{10} and ozone concentrations, to assess the rates of non-accidental deaths that occurred during a specified time period. Their data displayed an increase in the concentration of air pollution during the heat wave period. The combination of the rise in temperatures and air pollution concentrations was associated with a higher mortality rate, especially in those over 65 years of age. Increased daily temperatures alone accounted for 40% of the excess non-accidental deaths, whereas the temperature-air pollution interaction accounted for 20%.[15] This finding suggests that travel to developed countries may also challenge the traveller as a result of acute changes in the ambient air quality arising from heat waves and wildfires. Forest fires are predicted to become a more frequent occurrence secondary to climate change in the future.[16]

With regard to improving atmospheric air quality, measures have been introduced to decrease air pollution in preparation for the influx of travellers during mass gatherings. An example of this was the steps taken by China to improve air quality in preparation for the 2008 Summer Olympic Games in Beijing. Some of these measures included restricting pollution produced by factories, especially those reliant on coal combustion, as well as minimizing pollution produced by transportation, for example through the 'odd-even car ban' wherein, based on the license plate, drivers were allowed on the road on alternating days. A study conducted by Shen *et al.*[17] monitored the levels of the major air pollutants before, during, and after the 2008 Olympic games, in the Beijing region. The results displayed a drastic decline in the concentration of all of the major pollutants, except for ammonia, during the Olympic period, demonstrating the effectiveness of this emission reduction strategy.

An awareness of typical air pollution concentrations at travel destinations, through consultation of, for example, the WHO interactive air pollution maps, will allow the travel health professional to conduct a more informed individual travel risk assessment and enable the traveller to better prepare for, or even avoid, certain regions that may have a level of air pollution that could be hazardous to traveller health. However, when travel is unavoidable, before travelling to a region with decreased air quality, the traveller should be prepared to minimize any harm that may result from air pollution exposure. According to the International Association of Medical Assistance to Travelers, there are five factors to be considered in defending travellers against air pollution. These include health status (i.e. does the traveller have any current respiratory or cardiovascular diseases?), age (infants/children and the elderly require more caution), destination (urban vs. rural areas), length of trip, and the season (smog in humid days).[18] Travellers should be risk stratified during the pre-travel consultation and there should be seamless communication with their primary care provider or specialist as indicated. Travellers with COPD or asthma should carry an adequate supply of rescue medications to prevent or treat exacerbations. This medication rescue package should

Table 1. Air quality medical recommendations for travellers with respiratory disease

Measure	Travel health recommendation
Vaccinations	Recommend annual influenza vaccine
	Recommend pneumococcal vaccine
	Recommend hepatitis B vaccine
Medications	Carry prescription or list of current medications
	Equip traveller for self-management of exacerbations
	Bring medication rescue package, to include extra bronchodilator inhalers, oral corticosteroids and antibiotics
	Asthmatic travellers should monitor peak expiratory flow rate
Lifestyle	Encourage smoking cessation
	Minimize outdoor exercise in air polluted urban areas
	Comply with air pollution advisories
	Promote the use of hand sanitizer gel
Transportation	Choose underground metro instead of high diesel emission bus transport
	Encourage use of high-quality facemasks by pedestrians and cyclists
	Try to avoid pollution hotspots such as junctions and bus stations on high pollution days
	Travel outside of the rush hour if possible
	Keep car windows closed, especially if stuck in traffic

include bronchodilators, oral corticosteroids, and an antibiotic. It is also advised that travellers with cardiopulmonary disease should minimize ambient air exposure as well as exercise to decrease symptom exacerbation.[5,8,18] The dangers of carbon monoxide poisoning during international travel have been discussed in a previous article in this journal.[19]

Based on the US Air Quality Index score, a scoring index based on the concentration of criteria pollutants in a given area, where a score less than 50 is assigned to good air quality, while a score over 300 is assigned to hazardous air, travellers should adjust their level of activity and time spent outdoors. For example, patients with heart disease staying in a city with an AQI of 101–150 should reduce the time they spend outdoors. The use of certain types of facemasks, such as the N95 or R95 masks, may serve to filter many of the ambient air pollutants that would have otherwise been inhaled. These masks may be of benefit to general travellers, and more specifically the traveller with COPD and cardiovascular disease. Outside of the USA, a new European Air Quality Index has recently been launched by the European Environment Agency and the European Commission, featuring an interactive online map which displays the local air quality throughout Europe based on measurement of five key pollutants at monitoring station level.[20]

One of the emerging physical challenges faced by the traveller currently is exposure to environmental pollution. Air pollution is an issue that affects both the traveller as well as residents at the traveller's destination. There is a paucity of original research regarding the risk to travellers and how that risk is modified by factors such as age, pre-existing illness and duration of exposure. Future research should focus on the short- and long-term health effects of air pollution on international travellers, especially those with chronic medical conditions.

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