Lung health and outdoor air pollution - a review

Joseph Cacciottolo MD, DSc, FRCP

Environmental Management and Planning Division
Institute of Earth Systems, University of Malta
Email: joseph.cacciottolo@um.edu.mt

Educational aims

- To review the relationship between air pollution and lung health
- To increase awareness of the hazards of air pollution, particularly on lung health
- To discuss the impact of air pollution on three common lung diseases
- To provide a list of references as a base for further reading

Key words
Lung health, pollution, particulate matter, ozone

Abstract

The lung is one of the interfaces between the body and the exterior environment. The maintenance of lung health depends on several factors, among them one's genetic makeup, the environment, socioeconomic circumstances and natural ageing. Persons respond differently and uniquely to environmental circumstances, and this often makes the exposure-disease relationship difficult to assess.

Air pollution most commonly causes irritation of the respiratory tract, resulting in discomfort, cough and breathlessness. It is also a major factor in exacerbating existing respiratory diseases and may also be the potential cause of lung disorders. The relationships between air pollution, increased incidence of respiratory conditions and severity of airway diseases are well recognized and robustly supported by epidemiological, toxicological and clinical studies.

Outdoor air pollution is caused by aerosols and gases in amounts that may affect health, and the major contaminants in urban environments are a wide variety of particulate matter and ozone.

Common specific lung disorders are known to be linked with urban air pollution: asthma and chronic obstructive pulmonary disease are frequently exacerbated following exposure to contaminated air, while with regard to lung cancer, the relationship is a causal one. Air pollution also poses a significant public health problem and concomitant approaches are necessary in order to improve air quality and to lessen the negative impact of airborne pollution on lung health. Control and mitigation of this problem requires effective health education, and sound preventive strategies through a combined community, administrative and political approach.

Introduction

The human body interfaces with the outside milieu through skin, respiratory tract and the alimentary canal. The lungs are the most sensitive and delicate interface with the exterior environment; as such they react rapidly to irritation and are susceptible to harm, causing long term impairment and possible disability. The effects of interaction of the lungs with the environment depend on a wide variety of extrinsic and intrinsic factors, among them such personal factors as one's genetic makeup, socioeconomic circumstances and ageing itself.

A spectrum of personal and general adverse environmental factors, as well as certain occupations and working conditions influence lung health and may possibly lead to the development of pulmonary disorders. Persons respond differently and uniquely to identical environmental circumstances and an accurate assessment of risk may be confounded by genetic predisposition and interaction. The exposure-disease relationship may not be easy to identify and assess, not only because of the usually long-term and possibly variable exposure, but also because of the difficulty to separate the impact of comorbid conditions in the same individual.

A moderately active adult inhales about 20m^3 of air daily, of varying quality, and weighing more than 24kg. The respiratory tract itself is protected by various mechanisms. The nose, acting as a coarse pre-filter, traps relatively large particles (>5µm) and the epithelial lining acts as a filtration mechanism to trap smaller (>3-5µm) inhaled particles which are then moved out of the airways by the mucociliary process. The layer of mucus within the respiratory bronchioles traps very small particles and the alveolar fluid also affords a medium where particles are engulfed and destroyed by macrophages. The coughing and sneezing reflexes both act as protective mechanisms, as well as efficient systems for rapidly cleansing the respiratory tract from relatively large particulate matter, however they are ineffective with regard to gaseous air pollutants.

In clinical terms, exposure to polluted air impacts negatively on lung health by causing respiratory symptoms, principally coughing, breathlessness and chest tightness. It is also a major factor in exacerbating existing respiratory diseases and may also be the potential cause of lung disorders. Repeated

Key points

- Healthy lungs have extremely efficient protective mechanisms.
- Lung function and structure may be compromised by repeated exposure to contaminated air.
- Ambient air in urban areas with heavy traffic flow may be polluted by particulate matter and ozone.
- Exposures to both particulate matter and ozone have a negative impact on lung health, varying from discomfort to serious disability.
- Air pollution frequently causes exacerbation and deterioration of both asthma and chronic obstructive pulmonary disease, and may be a potential cause for lung cancer.
- Control of airborne pollution requires effective health education and preventive strategies, through combined community, administrative and political approaches.

exposure may lead to decline in lung function, increased susceptibility to chest infections, and permanent damage leading to premature death. Children, the elderly and persons with pre-existing cardiovascular disease, respiratory problems and diabetes mellitus appear to be at a greater risk to develop complications related to air pollution.[1,2]

The urban environment and outdoor air pollution

Outdoor air pollution is caused by solids, liquids, or gases in amounts that may adversely affect health, and the environment itself. In its milder form, air pollution often interferes with the comfortable enjoyment of life and property and most commonly causes irritation of the respiratory tract and the eye.

For many centuries, airborne dust, smoke and obnoxious fumes have been known to be sources of discomfort and illness. In the United Kingdom, the Industrial Revolution, beginning around 1730, was fueled primarily by the use of coal, and furnaces were often in close proximity to densely populated areas. Industrial use of coal, together with its use as a source of domestic heating, caused very high levels of air pollution, which were made worse when the weather was foggy.

The first well-documented widespread occurrence of airborne pollution happened in December 1930 in the Meuse valley, Belgium. Then, a lethal combination of industrial air pollution and thermal inversion, trapping fog over the heavily populated area of the narrow valley caused 'several thousand cases of acute pulmonary attacks' and 60 deaths. The Commission investigating this disaster was of the opinion that sulphur dioxide or its oxidation products were the cause for this disaster, however later studies suggest that the probable cause was acute intoxication by gaseous fluorine compounds.[3]

In December 1952, the London smog episode was the result of pollution from domestic coal use and industrial furnaces, together with adverse atmospheric conditions. Over a short period, tons of particulate matter filled the air, eventually turning the sky almost black, stinging eyes and causing acute respiratory symptoms. Visibility was so much reduced, that traffic flow was practically brought to a standstill. This episode was the immediate cause of around 4000 deaths, together with an indeterminate number due to delayed effects. Most of those who succumbed were elderly or already infirm.[4]

The damage that urban air pollution causes to health is multifactorial and usually follows exposure to multiple contaminants present concurrently. With regard to lung disorders, the relationship between air pollution, increased incidence of respiratory conditions and severity of airway diseases is well supported by epidemiological, toxicological and clinical studies.[5]

In European Union states, quite significant segments of urban dwellers are exposed to unacceptably high levels of airborne pollutants (Figure 1).[6] In a general European context, aerosol particles and to a lesser extent ozone, are the pollutants that mostly compromise lung and cardiovascular health.[7] There are no established safe levels for exposure to either particulate matter or ozone and they pose a risk to health even at concentrations below current guidelines for air quality.[8]

Particulate matter

Atmospheric particulate matter (PM) refers to a wide range and mix of particles of varying sizes and chemical composition: they may derive either from natural sources, or as a result of human activities and industry. Suspended dusts, pollen and sea-spray are the commoner natural PM, while combustion of fossil fuels in vehicles and power-generating plants are the source of most of 'man-made' or anthropogenic PM. The finer particles are classified as having an aerodynamic diameter of 2.5µm or less ($PM_{2.5}$).

The effects of chronic exposure of airborne PM on lung function and overall health are complex and to a very large extent beyond control of individuals. The negative effect of particulate air pollution on respiratory well-being is independent and consistent among different communities. Such a causal relationship holds for acute respiratory infections in children, obstructive pulmonary disorders, lung cancer, and for mortality from cardiopulmonary problems.[9] Children are especially vulnerable, as there is clear association between decreased growth in lung function and exposure to airborne PM. This association is consistent across communities that are ethnically different and geographically separate.[10,11]

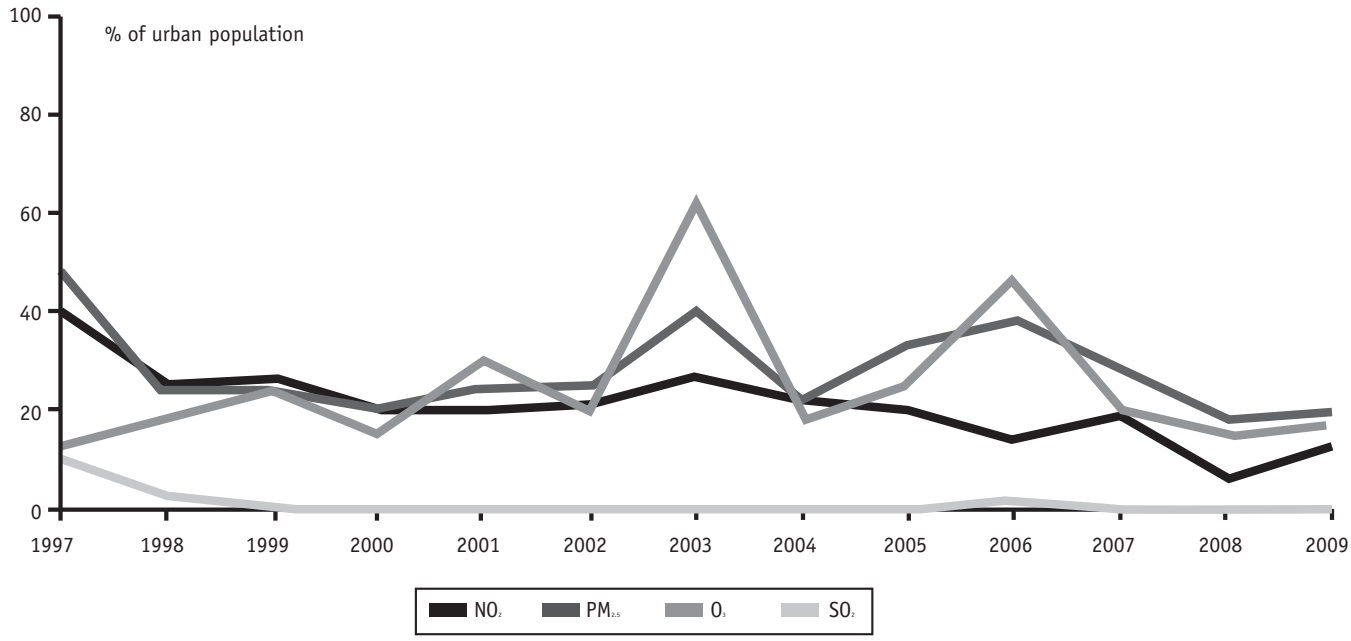
In the European Union, the average life expectancy is 8.6 months lower due to exposure to anthropogenic $PM_{2.5}$, while mortality rates due to air contamination are higher by 15–20% in cities with levels of pollution that exceed those observed in cities with relatively cleaner air.[12]

Ozone

Ozone (O_3) is formed as a result of chemical reactions involving daylight UV rays, following emission of precursor gases resulting principally from fuel combustion. Ozone is a powerful oxidizing agent that not only irritates the respiratory tract, but also reduces lung function. High ambient ozone concentrations are also clearly and independently associated with a significant risk of death from respiratory causes: the evidence is particularly compelling when considering results deriving from a large-scale study over an 18-year period and involving over 448000 subjects.[13]

Both acute and long-term exposures to ozone are associated with increased morbidity and mortality and the absolute effect of the gas on mortality is higher among older adults and during warmer weather.[14] Children, persons who work or exercise outdoors, persons with pre-existing respiratory disorders and persons suffering from cardiovascular conditions are especially vulnerable to damage caused by breathing ozone.[15,16,17]

Figure 1: Percentage of EU urban population potentially exposed to air pollution exceeding acceptable EU air quality standards. Source: EEA, 2011c (CSI004).5



Specific lung diseases and air pollution

Asthma

Air pollution is a recognized cause for destabilizing well-controlled asthma, and for exacerbating this inflammatory condition. This is especially so among children, who are more susceptible to air pollution than adults, even when levels of pollution are relatively low and within 'acceptable' ranges.[18,19]

Hospital admissions because of acute asthma may be due to a variety of provoking factors, among them exposure to air polluted with a wide range of PM. The causal relationship between hospitalization rates for asthma and ambient air contamination is both consistent and widespread across all age-groups and among different communities. Exposure to traffic-related air pollution over a long period also increases the risk of hospitalization because of unstable asthma among older persons, however children are probably at an even higher risk.[20]

There is a clear relationship between ambient ozone concentrations and increased symptoms of asthma. Persons with asthma might be more sensitive to ozone, and may therefore develop respiratory symptoms either at lower concentrations of the gas, or with greater magnitude than persons who do not have this condition. Admissions to hospital for control of asthma have been found to be more frequent on days following exposure to raised ambient ozone levels, while minor adverse respiratory symptoms and decreased lung function also persist for several days. Predictably, the effects tend to be more pronounced during the warm season.[21]

While the role of air pollution as a trigger factor for exacerbating pre-existing asthma is well documented, there is no evidence that it may actually cause asthma, and any role that it may possibly play in initiating it, is yet undetermined.

Cancer of the lung

Several large epidemiological studies have documented a link between air pollution and lung cancer in non-smokers. Persons who live in areas with high ambient air pollution are more likely to develop lung cancer than those who live in areas with cleaner air. Recent evidence shows a clear relationship between concentrations of ambient $PM_{2.5}$ over a 26-year period and mortality from lung cancer among persons who never smoked.[22]

The relationship between ambient diesel exhaust specifically and lung cancer is less clear, and most of the evidence derived from population studies is not considered adequate to prove the diesel-lung cancer hypothesis.[23] However, with regard to occupational exposure to diesel fumes, a large multicentre study showed a consistent association between cumulative diesel motor exhaust and increased risk of lung cancer: this association was well-adjusted for bias and confounding factors.[24]

Chronic obstructive pulmonary disease

The role of air pollution as a direct cause of chronic obstructive pulmonary disease (COPD) has been explored by several studies, however any possible causal relationship is still unclear.[25] A large Danish cohort study suggests that exposure to high levels of air pollution in the long-term may itself contribute to the development of COPD. Persons who were exposed for more than 25 years ran a 7% higher risk, while the impact of air pollution on persons who also had asthma and diabetes was greater.[26]

The role of air pollution as a complicating factor in COPD as a pre-existing lung condition is however not in any doubt, and the relationship has been well-defined.[27] There is evidence to suggest that some patients are more susceptible than others to this environmental trigger and react with increasing symptoms and acute exacerbations: this has a cumulative effect on emergency department visits, hospital admissions and even mortality.[28,29]

Conclusion

Air pollution poses clear and multiple health hazards to individuals; however it is also a

significant public health problem. Several concurrent approaches are necessary in order to improve air quality and lessen the negative impact of airborne pollution on lung health. Control of this problem requires effective health education, and sound preventive strategies through a combined community, administrative and political approach.

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