Health Effects of Air Pollution

The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, the individual's health status and genetics. People who exercise outdoors, for example, on hot, smoggy days increase their exposure to pollutants in the air.

The health effects caused by air pollutants may range from subtle biochemical and physiological changes to difficulty breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions. These effects can result in increased medication use, increased doctor or emergency room visits, more hospital admissions and even premature death.

Human Respiratory System

The health of our lungs and entire respiratory system is affected by the quality of the air we breathe. In addition to oxygen, this air contains other substances such as pollutants, which can be harmful. Exposure to chemicals by inhalation can negatively affect our lungs and other organs in the body. The respiratory system is particularly sensitive to air pollutants because much of it is made up of exposed membrane. Lungs are anatomically structured to bring large quantities of air (on average, 400 million litres in a lifetime) into intimate contact with the blood system, to facilitate the delivery of oxygen.

Lung tissue cells can be injured directly by air pollutants such as ozone, metals and free radicals. Ozone can damage the alveoli -- the individual air sacs in the lung where oxygen and carbon dioxide are exchanged. More specifically, airway tissues which are rich in bioactivation enzymes can transform organic pollutants into reactive metabolites and cause secondary lung injury. Lung tissue has an abundant blood supply that can carry toxic substances and their metabolites to distant organs. In response to toxic insult, lung cells also release a variety of potent chemical mediators that may critically affect the function of other organs such as those of the cardiovascular system. This response may also cause lung inflammation and impair lung function.

Structure and Function

The human respiratory system is dominated by our lungs, which bring fresh
oxygen (O₂) into our bodies while expelling carbon dioxide (CO₂). The oxygen travels from the lungs through the bloodstream to the cells in all parts of the body. The cells use the oxygen as fuel and give off carbon dioxide as a waste gas. The waste gas is carried by the bloodstream back to the lungs to be exhaled.

The lungs accomplish this vital process - called gas exchange - using an automatic and quickly adjusting control system. This gas exchange process occurs in conjunction with the central nervous system (CNS), the circulatory system, and the musculature of the diaphragm and the chest.

The human respiratory system can be divided into the upper respiratory tract and the lower respiratory tract. The upper respiratory tract includes the following rigid structures:

**Nasal cavities:** Filter the air we breathe and provide a sense of smell.

**Pharynx:** Acts in the respiratory and the digestive system.

**Larynx:** Link between the pharynx and the trachea. Generates the voice with the presence of vocal folds.

**Trachea:** The trachea is the bond with the lower respiratory tract. This is a flexible structure allowing the air to go down to the lungs.

In addition to gas exchange, the lungs and the other parts of the respiratory system have important jobs to do related to breathing. These include:

- Bringing all air to the proper body temperature.
- Moisturizing the inhaled air for necessary humidity.
- Protecting the body from harmful substances by coughing, sneezing, filtering or swallowing them, or by alerting the body through the sense of smell.
- Defending the lungs with cilia (tiny hair-like structure), mucus and macrophages, which act to remove harmful substances deposited in the respiratory system.

**Diagram of Human Respiratory System**
The respiratory system is sensitive to air pollution. The cardiovascular system can be affected as well.

**Human Cardiovascular System**

The cardiovascular system has two major components: the heart and a network of blood vessels. The cardiovascular system supplies the tissues and cells of the body with nutrients, respiratory gases, hormones, and metabolites and removes the waste products of cellular metabolism as well as foreign matter. It is also responsible for maintaining the optimal internal homeostasis of the body and the critical regulation of body temperature and pH.

The inhalation of air pollutants eventually leads to their absorption into the bloodstream and transport to the heart. A wide spectrum of chemical and biological substances may interact directly with the cardiovascular system to cause structural changes, such as degenerative necrosis and inflammatory reactions. Some pollutants may also directly cause functional alterations that affect the rhythmicity and contractility of the heart. If severe enough, functional changes may lead to lethal arrhythmias without major evidence of structural damage to the myocardium.

There also may be indirect actions secondary to changes in other organ systems, especially the central and autonomic nervous systems and selective actions of the endocrine system. Some cytokins released from other inflamed organs may also produce adverse cardiovascular effects, such as reducing the mechanical performance and metabolic efficiency of the heart and blood vessels.

Many chemical substances may cause the formation of reactive oxygen. This oxidative metabolism is considered to be critical to the preservation of cardiovascular function. For example, oxygen free radicals oxidize low-density lipoproteins, and this reaction is thought to be involved in the formation of the atherosclerotic plaques. Oxidized low-density lipoproteins can injure blood vessel cells and increase adherence and the migration of inflammatory cells to
the injured area. The production of oxygen free radicals in heart tissues have been associated with arrhythmias, and heart cell death.

**Heart and Lung Diseases**

Heart and lung illnesses and diseases are common in Canada, and there are many factors that can increase the chances of contracting them such as smoking and genetic predisposition. The role of air pollution as the underlying cause remains unclear but is the subject of considerable research. However, it is clear that air pollution, infections and allergies can exacerbate these conditions. An early diagnosis can lead to appropriate treatment and ensure a normal or close to normal quality of life. In many cases however, there is no cure and those affected may die prematurely. The following are the most prevalent diseases:

**Minor Lung Illnesses** - the common cold is the most familiar of these, with symptoms including sore throat, stuffy or runny nose, coughing and sometimes irritation of the eyes.

**Lung Infections** - croup, bronchitis, and pneumonia are caused by viruses or bacteria and are very common. Symptoms may include cough, fever, chills and shortness of breath.

**Asthma** - is an increasingly common chronic disease among children and adults. It causes shortness of breath, coughing or wheezing or whistling in the chest. Asthma attacks can be triggered by a variety of factors including exercise, infection, pollen, allergies and stress. It can also be triggered by a sensitivity to non-allergic types of pollutants present in the air such as smog.

**Chronic Obstructive Pulmonary Disease (COPD)** - is also known as chronic obstructive lung disease and encompasses two major disorders: emphysema and chronic bronchitis. Emphysema is a chronic disorder in which the walls and elasticity of the alveoli are damaged. Chronic bronchitis is characterized by inflammation of the cells lining the inside of bronchi, which increases the risk of infection and obstructs airflow in and out of the lung. Smoking is responsible for approximately 80% of COPD cases while other forms of air pollution may also influence the development of these diseases. Symptoms include cough, production of mucous and shortness of breath. It is important to note that no cure exists for people suffering from COPD although healthy lifestyle and appropriate medication can help.

**Lung Cancer** - is the most common cause of death due to cancer in women and men. Cigarette smoke contains various carcinogens and is responsible for most cases of this often fatal disease. The symptoms of lung cancer begin silently and then progress to chronic cough, wheezing and chest pain. Air pollution has been linked somewhat weakly to lung cancer.

**Coronary Artery Disease** - refers to the narrowing or blocking of the arteries or blood vessels that supply blood to the heart. This disease includes angina and heart attack which share similar symptoms of pain or pressure in the chest. Unlike angina, the symptoms caused by heart attack do not subside with rest and may cause permanent damage to the heart. Smoking, lack of exercise, excess weight, high cholesterol levels in the blood, family history and high blood pressure are some of the factors that may contribute to this disease.

**Heart Failure** - is a condition in which the heart is unable to cope with its workload of pumping blood to the lungs and the rest of the body. The most common cause is severe coronary artery disease. The main symptoms are shortness of breath and swelling of the ankles and feet.

**Heart-Rhythm Problems** - are irregular or abnormal rhythms of the
heart beat. In some cases heart-rhythm problems are caused by coronary artery disease. Symptoms of heart-rhythm problems include fluttering in the chest (palpitation) and feeling light-headed. Some heart-rhythm problems are life-threatening and need emergency treatment.

Pyramid of Health Effects

Air pollution can affect both the respiratory and cardiac systems. The health effects of air pollution can be seen as a pyramid, with the mildest but not common effects at the bottom of the pyramid, and the least common but more severe at the top of the pyramid. The pyramid demonstrates that as severity decreases the number of people affected increases.

Health Endpoints Associated with Increased Air Pollutants Levels

Mortality: All non-accidental mortality causes

Hospital Admissions: Cardiovascular and Respiratory Hospital Admissions

Emergency Room Visits: Visit to an emergency department

Asthma Symptom Days: Exacerbation of asthma symptoms in individuals with diagnosed asthma

Restricted Activity Days: Days spent in bed, missed from work, and days when activities are partially restricted due to illness

Acute Respiratory Symptoms: Respiratory-related symptoms such as chest discomfort, coughing and wheezing

Population at Risk

Although everyone is at risk from the health effects of air pollution, certain sub-
populations are more susceptible. Individual reactions to air contaminants depend on several factors such as the type of pollutant, the degree of exposure and how much of the pollutant is present. Age and health are also important factors.

The elderly and people suffering from cardio-respiratory problems such as asthma appear to be the most susceptible groups.

Children and newborns are also sensitive to the health effects of air pollution since they take in more air than adults for their body weight and consequently, a higher level of pollutants. People who exercise outdoors on hot and smoggy days are also at greater risk due to their increased exposure to pollutants in the air.

Leading Causes of Hospitalization

Leading Causes of Hospitalization
Number and Percentage of Separation by Subgroup Canada 96-97

(Total Number of hospitalizations: 8 168 789, Source: Statistics Canada, 1999)

Respiratory and cardiovascular diseases are among the leading causes of hospitalization in Canada. In 1996-1997 there were 3.16 million hospital admissions in Canada of which cardiovascular and respiratory diseases accounted for 15% and 9%, respectively.

Air pollution exacerbates the condition of people with respiratory and cardiovascular diseases and causes measurable increases in the rates of hospitalization for these diseases. We do not yet understand the role of air pollution in causing these illnesses in the Canadian population.

Leading Causes of Death
Cardiovascular and respiratory diseases are among the leading causes of death in Canada. In 1997, 37% and 9% of over 200,000 deaths were related to cardiovascular and respiratory diseases respectively.

Air pollution causes measurable increases in non-accidental mortality.

**Estimating Health Benefits**

When examining a specific pollution-reduction option (such as changing gasoline composition) regulators may estimate the reduction in health effects that are expected, and the value to society of avoiding those health problems.

As a society, we pay for the health effects of air pollution in many ways. Additional health care costs for the treatment of these effects may come from any of the following: hospital admissions, visits to the emergency room or doctor's office, homecare service, medication such as inhalers for asthma. Other considerations include lost productivity in the workplace, lost wages due to sick time, out of pocket expenses incurred while ill (e.g., additional child care costs), and, finally lost quality of life or life itself.

**Steps in Estimating Health Benefits**

- Baseline gasoline composition and changes to composition
- Changes in ambient air concentrations of pollutants
- Changes in health effects
- Combustion of gasoline
- Changes in value of health
A recent study examined the economic value of reducing the health effects of air pollution by introducing cleaner vehicles and fuels in Canada. This study found that the economic value of avoiding these health effects was $24 billion over a period of 24 years, compared to a cost of $6 billion to implement the program. This methodology has been used by Health Canada and Environment Canada in a number of initiatives to examine the benefits of control measures. To see an example of this process access the Sulphur in Gasoline Study at http://www.ec.gc.ca/energ/fuels/reports/final_sulphur/execsum_e.htm

Important Notices