Health Effects of Indoor Air Pollution

What are the risks to health from air pollution?

Because most people spend the vast majority of their time indoors, the health effects include those arising from exposure to both pollutants generated outdoors and those released indoors. Health risks due to outdoor pollutants, i.e. those arising from traffic and industrial processes, have been recognised for many years. Health effects of outdoor pollutants are wide ranging and include an increase in carcinogenic risk (e.g. benzene) and irritancy of the eyes and respiratory system (ozone). It has been estimated that air pollution reduces the life expectancy of every person in the UK by an average of 7-8 months, with estimated equivalent health costs of up to £20 billion each year.

There are a number of sources of the classic outdoor pollutants in the indoor environment including combustion of gas, coal and wood for heating and cooking, environmental tobacco smoke from smoking of cigarettes, vapour from vehicles in attached garages (benzene), burning of candles and incense, emissions from printers and photocopiers and some types of air 'cleaners' (ozone). In addition there are a wide range of other substances including those released from the large range of building, furnishing and consumer products present indoors, by the occupants themselves, by microbiological growth, and present in soil gas that enters the building from the ground.

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What are the health effects of indoor pollutants?

Poor IAQ is believed to have an important causative or aggravating influence on the following diseases:

- Allergic and asthma symptoms
- Lung cancer
- Chronic obstructive pulmonary disease (COPD)
- Airborne respiratory infections
- Cardiovascular disease (CVD)
- Odour and irritation (SBS symptoms)

What pollutants are of concern?

The main groups of substances known to cause indoor pollution are:

- Radon
- Volatile organic compounds (VOC): Formaldehyde, Semi-volatile Organic Compounds (SVOC), Microbial volatile compounds (MVOC)
- Inorganic gases: carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), Sulphur dioxide (SO_2)
- Ozone
- Water vapour
- Particles

Health effects in detail

Allergic and asthma symptoms are increasing throughout Europe affecting between 3-8% of the adult population with higher prevalence in infants. The cause of allergic diseases is considered to be a complex interaction between genetic and environmental factors and asthmatic patients are sensitive to allergens present in the indoor environment and are often hyperactive to a number of gasses and particles. Risk factors identified most frequently include formaldehyde or particleboard, phthalates or plastic materials and recent painting. Building dampness and mould has been associated with an approximately 30 to 50% increase in a variety of respiratory and asthma-related health outcomes.

Lung cancer is the most common cause of death from cancer in the EU (about 20% of all cases). Most are due to active smoking, but it is estimated that 9% are due to radon exposure in the home and 0.5% in males and 4.6% in females are due to exposure to environmental tobacco smoke (ETS). There is some evidence of risk due to combustion particles including ultrafine and fine particles in ambient air, diesel exhaust and indoor cooking oil and coal burning.

COPD is a chronic respiratory disorder that is usually progressive and associated with an inflammatory response of the lungs to noxious particles or gases. It is estimated that the prevalence of clinically relevant COPD in Europe is between 4 and 10% of the adult population. About 70% of COPD related mortality is attributed to cigarette smoking. Other risk factors identified are ETS, biomass combustion fumes, particles in ambient air and long term exposure to mould/dampness.

Airborne infectious diseases include Legionnaire's disease, tuberculosis, flu and SARS (Severe Acute Respiratory Syndrome). Reservoirs of aquatic systems such as cooling towers, evaporative condensers, humidifiers, have been the source of airborne agents in outbreaks of Legionella and pneumonia. Symptoms of these diseases can be aggravated by exposure to ETS and combustion particles.

CVD is the leading cause of death in industrialised countries accounting for 42% of deaths in the EU. Causes include exposure to ETS, particles, CO and other gaseous pollutants (NO_2 in particular).

SBS describes cases where building occupants experience acute symptoms and discomfort that are apparently linked to the time spent in the building, but for which no specific illness can be assigned. Symptoms include respiratory complaints, irritation and fatigue. Sensory perception of odours leads to a perception of poor air quality and consequently stress initiated behavioural responses (e.g. opening windows). Other environmental stressors such as noise, vibration, crowding, ergonomic stressors and inadequate lighting can produce symptoms similar to those caused by poor air quality. The negative effects can reduce productivity in offices and learning ability in schools.

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Pollutants in detail

Radon is a naturally occurring radioactive gas that can enter buildings from the ground and the amount of ingress depends upon a number of factors including local geology, the type of foundation, the positioning of service pipe work and internal ventilation levels. Measures such as installation of gas proof membranes in the foundations of new buildings can significantly reduce levels of radon gas.

VOCs are emitted over periods of weeks or years from construction and furnishing products and have the potential to cause poor air quality. VOCs are also released from consumer products including electrical goods such as computers and printers as well as cleaning products and air fresheners. Environmental tobacco smoke (ETS) contains a complex mixture of organic compounds and while smoking is banned in the workplace and public buildings in some European countries it remains a significant source in many homes.

Formaldehyde is a very volatile organic compound that has been widely studied because of its release from a range of building and consumer products.

SVOCs have a relatively low vapour pressure and therefore tend to occur at lower concentrations in indoor air than the more volatile VOCs. They include plasticisers used in polymeric materials such as vinyl floorings and paints, pesticides such as DDT and pentachlorophenol, and polyaromatic hydrocarbons (PAHs) produced during fuel combustion and present in coal tar and in tobacco smoke.

MVOCs are volatile compounds released as the result of the metabolism of fungi; they include ethanol and a range of higher alcohols and ketones.

The principal sources of *inorganic* pollutant *gases* in the indoor air are the outdoor air, combustion of fuel, and respiration by people and animals. The main sources of combustion gases in buildings are related to space heating (especially open-flued or unflued gas and paraffin heaters), water heating and cooking. Other sources include tobacco smoke and vehicles (in attached garages or close to ventilation air intakes).

CO_2 is a natural constituent of air and only in exceptional circumstances is it present in sufficient amounts to be a danger to health. It can be present in buildings as a result of respiration of people and animals, as a product of combustion and as a component of soil gas. It is widely used as an indicator of ventilation rate and, effectively, as a proxy for body odour.

CO is a colourless, odourless gas, produced by the incomplete combustion of most fuels. Incomplete combustion can occur, for example, when inadequate ventilation to an appliance results in depletion of the oxygen content of the air at the point of combustion. For example carbon monoxide can be produced by faulty combustion appliances at a rate sufficient to cause fatal poisoning in homes and there is concern that cases of chronic poisoning may be undetected.

The major indoor sources of NOx, including NO_2, are gas-fuelled cookers, fires, water heaters and space heaters, and oil-fired space heaters. Sulphur dioxide (SO_2) is produced by burning sulphur-containing fuels such as coal and oil.

Ozone is primarily a pollutant of ambient air produced by photochemical reaction. It undergoes reaction indoors with surfaces and airborne pollutants to produce new organic compounds and particles.

Water vapour is produced by people, during activities such as cooking, cleaning and washing, as well as through normal respiration. The amount of water vapour in the air has direct effects on health and comfort and is also important in relation to the occurrence of biological pollutants.

Particles in the air may arise from a wide variety of sources, both natural and related to human activity. Particles generated indoors are mainly from mechanical processes such as cleaning and physical activity by occupants. Particles in the submicron ranges are generated during combustion as well as from secondary processes such as gas to particle conversion and nucleation or photochemical processes. The main indoor sources of these submicron particles include smoking and cooking and the operation of gas burners, ovens and electric toasters. Fibres are a particular type of particle and the use of asbestos in buildings has been an important route of worker and population exposure.

There are four main types of *particles of biological origin* that are significant for human health in most buildings: faecal pellets of the house dust mite, fungal particles, bacteria and pollen. Other allergenic particles can also be present in the indoor air, for example from domestic animals (e.g. cats, dogs, birds) and pests (e.g. cockroaches). Pathogenic (disease-causing) bacteria are present in the indoor air, originating from people and water spray, and potentially other sources such as food and animals. A wide variety of species of non-pathogenic bacteria also occur naturally in buildings. Pollen is mainly from the outdoors, with tree pollen predominating during the early spring and the grass pollen season occurring during late spring and early summer.

High humidity and dampness from water leaks can cause damage to materials by mechanical and chemical processes that result in degradation and release of substances such as formaldehyde from products containing urea formaldehyde resins, ammonia from certain floor screeds and odorous alcohols from some vinyl floorings. In addition dampness may encourage microbiological growth resulting in further material degradation and also release of products of metabolism and biological particulates such as fungal spores.

Asbestos is present in many buildings and presents a risk of cancer if fibres are inhaled. Strictly controlled removal by specialist contractors is required but it is often sufficient to manage the risk adequately by ensuring the material is not disturbed.

What can be done to prevent poor indoor air quality?

It should be emphasized that source control is the first strategy to apply. In order to obtain good IAQ in buildings, it is necessary to select low emission products, but also to properly design, operate and maintain ventilation systems. Regulations for products that possibly emit compounds of concern are potentially an effective approach with benefits for both new and existing buildings, especially for compounds that are (potentially) carcinogenic. In fact, when a compound has been clearly identified as being carcinogenic it should be appropriately controlled (e.g. the banning of asbestos is a good example, and limits on release of formaldehyde from products used indoors).

The key issues are;

- *Good quality outdoor air*: For new (and refurbished) buildings regard should be given to the location where the supply air is drawn (either MV inlet or opening window) and traffic and the sitting of an MV outlet or exhaust from combustion appliances. In a minority of buildings with full MV systems the supply air may be filtered to remove some airborne particulates.
- *Avoid re-entrainment of outgoing air* into the building supply air.
- *Adequate ventilation*; both general background and provision of rapid ventilation.
- *Maintenance* of ventilation provision.
- *Control of indoor pollution sources* by availability and informed selection of products (see 'Low emitting products').
- *Informed (about IAQ issues) client-customer chain* (from material and product suppliers to designers, specifiers of products, facilities managers, maintenance personnel, and finally building occupants themselves) that work together to achieve good IAQ in new and refurbished buildings.
- *Regular cleaning of interior surfaces*.
- *Make building users aware* of need for ventilation and control of sources of indoor pollutants.

What levels of pollutants are safe?

A number of national and international guidelines for maximum concentrations to protect the health and well being of building occupants against adverse health effects is available. These are relatively few in number compared to the wide range of substances that may cause problems for occupants and specialised knowledge is often required to assess the significance of measurements of indoor air pollutants. For the wide range of substances without guidelines it may be necessary to examine the available toxicity literature to assess the possible risk to health. Also measured values can be compared to available 'reference values' that represent the typical range present in buildings.

Further reading

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