#4243

Indoor pollution control

The reaction of human beings to pollution in the indoor environment has been studied in Denmark. *Geo Clausen explains the source of some major pollutants and how they can be controlled with good ventilation

Increasing energy prices has led to recent efforts to reduce the cost arising from mechanical and outdoor air intake. At the same time many new pollution sources have been introduced in the buildings. This has led to a build-up of pollution in the indoor environment.

As the sources of pollution are numerous, so are the impacts they have on man. The most important factors are, of course, those which have a direct effect on our health. These can be divided into acute and long-term effects. Fortunately our indoor climate is seldom so poor that we become seriously ill after a short period spent indoors. However, allergic reactions and biological infection are examples of acute effects.

Allergy can also be seen as a long-term effect, because in many cases allergies appear after long-term exposure to the allergens in question. Lung cancer caused by continuous inhalation of asbestos fibres is another example of a long-term effect. What is unfortunate about these effects is that they seldom are noticed soon enough so suitable provision for the reduction of harmful effects can be introduced. Furthermore it is often difficult to estimate the risk of developing an illness as a consequence of long-term exposure to a poor atmospheric indoor climate.

Most complainants about poor indoor air quality concern annoyance such as odour and irritation of the eyes, nose and the upper respiratory passages. Smell is perceived immediately after entry into a room affected by malodorous pollutants, whereas irritation is often experienced after some exposure (typically after 5–60 minutes of exposure).

In the following article are described some of the pollutants found in the non-industrial indoor environments. Although the pollutants are described individually it is important to understand that poor indoor air quality often is the result of many pollutants being present at the same time.

Bioeffluents from human beings

Human beings emit a large variety of gaseous bioeffluents from sweat, respiration and digestion in the mouth, stomach and intestinal canal. The bioeffluents comprise numerous gases in such small concentration that they are often difficult to measure even with modern equipment. However, their presence is easily detected by the human nose.

For more than a hundred years human bioeffluents have been considered the most important, and in many cases the only, pollution source in the non-industrial indoor environment. At the turn of the century human bioeffluents were believed to be toxic and "crowd-poisoning" was feared. Although science since then has proved that the gaseous bioeffluents in the concentrations found in the indoor environment are not harmful to man, the odour problem remains.

The emission rate of bioeffluents is subjected to large interpersonal differences and depends on the diet, activity level and standard of personal hygiene. The best indicator of the concentration of bioeffluents is carbon dioxide, which man emits in large quantities and is fairly easy to measure. Carbon dioxide itself is odourless and harmless at concentration usually found in the indoor climate, but it proves a good quantitative indicator of human presence in a room.

Figure 1 shows the dose-response relationship between concentrations of bioeffluents expressed by concentrations of carbon dioxide and the percentage of dissatisfied visitors immediately after entry into a room.

The illustration shows that if bioeffluents from human beings are the only pollution source in a room, and a maximum of 20% dissatisfied is accepted immediately after entry into the room the concentration of carbon dioxide emitted from human beings must not exceed 1000 ppm, equivalent to a ventilation rate of approximately 8 l/s per person (1,2). However, other pollution sources will always be present and therefore the ventilation rate should be given in l/s per olf instead of l/s per person. (The unit olf, which is the emission rate of air pollutants from a standard person, can be used to quantify the source strength of all pollutants perceived by human beings[3]).

Figure 1

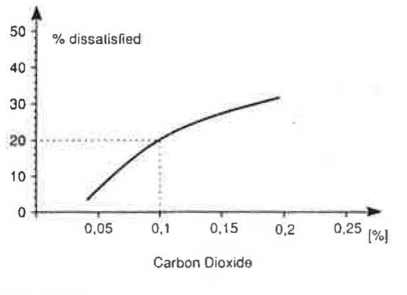
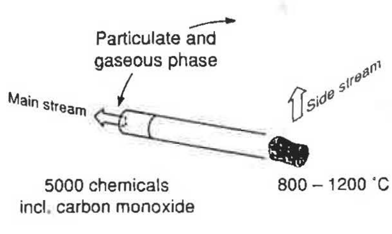


Figure 2



Tobacco smoke

Tobacco smoke is often a dominating pollutant in a room. As shown in Figure 2 the burning firecone of a cigarette reaches a temperature of 800–1200°C, resulting in an emission of very complex composition. More than 5000 chemical substances have been identified in a particulate and gaseous phase. When the smoke is mixed with indoor air it is often denoted environmental tobacco smoke (ETS). Numerous studies have shown that active smoking is dangerous to man. However, the potential health risk associated with ETS is still discussed by epidemiologists and other medical experts. But no expertise is needed to document that tobacco smoke is a source of odour and irritation of eyes, nose and throat. Experiments have shown that if the criteria of maximum 20% dissatisfied is applied, approximately ten times more outdoor air is required to control the odour (120 m^3 per cigarette (2)) than to control irritation (12 m^3 per cigarette (4)) from ETS. In Figure 3 the dose-response relationship between the concentration of tobacco smoke expressed in ppm of carbon monoxide and the percentage of dissatisfied visitors to a room is shown. As with carbon dioxide and human bioeffluents it is not the carbon monoxide that is *creating* the problem. Carbon monoxide is only used to quantify the concentration of tobacco smoke. The figure is based on odour discomfort and shows that 20% dissatisfied corresponds to approximately 0.4–0.5 ppm of carbon monoxide. Given normal rates of smoking (approx 0.6 cigarette/h per person) this corresponds to a supply of outside air of 20 l/s per person.

Tobacco smoking contributes to the perceived air pollution in a space not only by the smoke produced, but also indirectly by out-gassing from materials polluted by previous smoking[5].

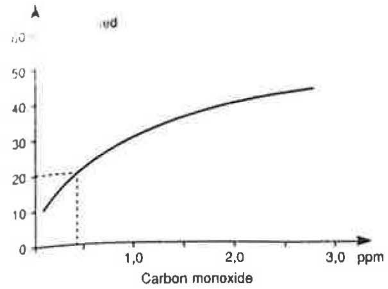


Figure 3

Th. .direct contribution may be of similar magnitude as the direct contribution of smoking to the perceived air pollution.

To reduce the annoyance from ETS the particulate phase is sometimes removed from the smoke by use of an electrostatic filter. But since both the odourous and irritating components are found mainly in the gaseous phase fil. on this will have little or no eff. on the perceived air quality (6,4). However, particle filtration may still be a good idea from a health point of view.

Volatile organic compounds (VOC)

In the course of the last few decades many new materials have been introduced into the indoor environment as building materials, furniture, etc. These materials have many excellent qualities, but they often also have a negative influence on the indoor air quality: they emit Volatile Organic Compounds (VOC) to the indoor air.

Normally a chemical analysis of the indoor air will reveal hundreds of these compounds in low concentrations. The number of compounds fo... is only limited by the detection limit of the analytical equipment. But how does the presence of VOC in the indoor air affect man?

It has been suggested that even small concentrations of VOC in the indoor air may play an important role in the sick building syndrome (SBS) (7). The odorous and irritating effect of many of the VOC found indoors have been studied, but little kn. ledge exists when it comes to the combined effect of hundreds of VOC present in the air at the same time.

Products of combustion

Tobacco smoke is not the only product of combustion to be found in indoor air. Other sources include kerosene heaters, gasfired water-heaters and kitchen ranges, fireplaces, etc. Combustion is often accompanied by annoying odours but it may also be a serious threat to the health and well being of people. The two main components of interest are carbon monoxiode and nitrogen dioxide.

Carbon monoxide is an odourless and colourless gas which arises from incomplete combustion. When inhaled, carbon monoxide forms carboxyhaemoglobin with the haemoglobin in blood as shown in Figure 4. The presence of carboxyhaemoglobin inhibits the normal uptake of oxygen in the blood.

Nitrogen dioxide, a colourless gas with a characteristic odour, is formed in high temperature combustion, as in gas-fired kitchen ranges and water-heaters. High concentrations of nitrogen dioxide can occur if these installations are unvented. The impact of nitrogen dioxide on many is similar to that of carbon monoxide, but in addition, small changes or the lung function have also been associated with exposure to nitrogn dioxide (8).

Radon

Radon is a radioactive gas formed when radium decays. Radium is found all over the Earth in concentrations which depend on geological conditions. Radon cannot be detected by the senses as the gas is odourless and invisible. Radon has a half-life of 3.8 days and decays to form the short-lived "daughter" isotopes polonium-218, lead-214 and bismuth-214, until it reaches the more stable decay product of lead-210.

Figure 5 shows the sequence of decay. Alpha and beta radiation from the "daughter" isotopes, deposited in the lungs, constitute the major proportion of the total radioactive radiation we receive, and results in a sometimes significant risk of lung cancer. It is difficult to quantify the health risk associated with radon in buildings, but in the United States the Environmental Protection Agency (EPA) has estimated that about 5000 to 20 000 lung cancer deaths a year in the United States may be attributed to radon (9).

The figure also shows how radon seeps into a building, primarily through leaks in the cellar. Things can go completely wrong if the building is sited on ground with high concentration of radon, and, as the figure shows, the building has an air exhaust system with no make-up air. The ventilator creates a low pressure in the building, through which radon is simply sucked into the building. Balanced ventilation is one way of preventing this.

Particles and Fibres

Particles is used as a generic term for all liquid or solid material with an effective diameter greater then molecules and less than about 1000 micrometers.

Tobacco smoke is the dominating source of particles in the indoor environment. Oblong particles the length of which are more than three times the diameter are defined as fibres. During inhalation a substantial proportion of particles larger than approximately 2–3 micrometers, are picked up by hair and mucous membranes in the nose and the upper air passages. Meanwhile smaller particles often continue right down into the lungs. We do not know very much about the effect this has on health. One exception, however, is asbestos which can cause diseases of the lung such as asbestosis and cancer of the lung and lung tissue, even after exposure to quite small doses. Our present knowledge does not attribute an equivalent health risk to mineral wool, but, as all "do-it-yourself" insulation workers know, it can be physically irritating for the skin and the mucous membranes. Similar comfort problems caused by the physical properties of particles do not normally occur, but particles can transport irritating chemicals to the mucous membrane.

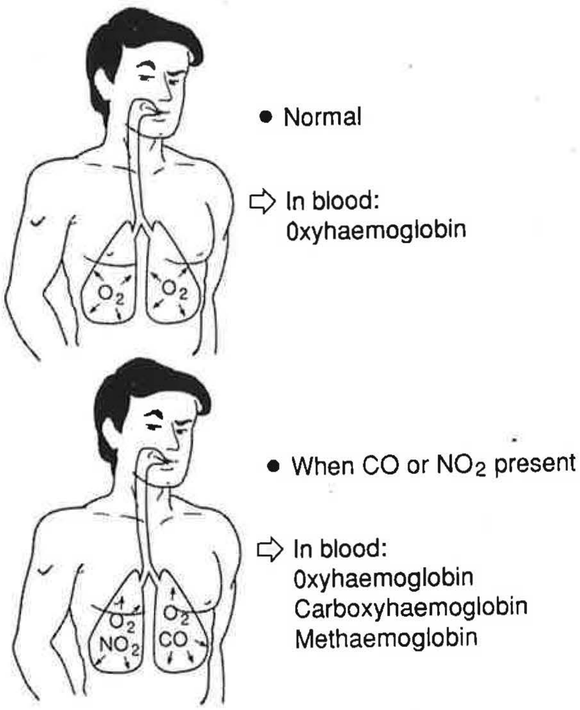


Figure 4

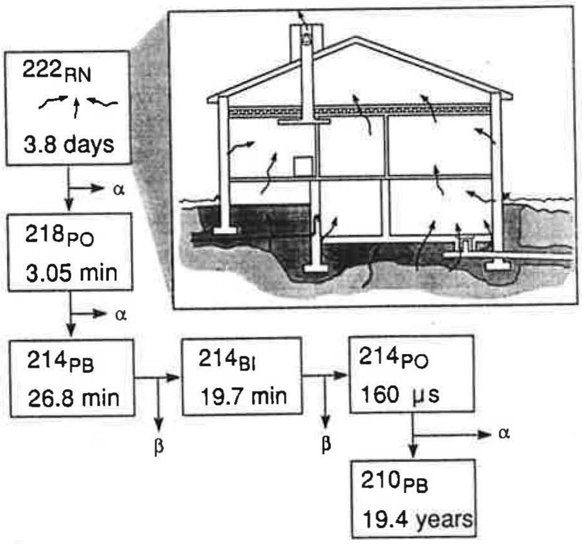


Figure 5

Microorganisms and allergens

Bacteria, viruses, fungal spores, pollen, house dust mites, etc are unavoidable in the indoor environment. We can divide the inconvenience connected with them into infectious sicknesses such as colds and influenza, allergic reactions and obnoxious odours.

Many microorganisms flourish in conditions of high humidity, as found in air humidifying equipment. Microbial pollution of badly maintained spray humidifiers has given the name to the illness "humidifier fever", which has symptoms of high temperature, head-ache, tiredness and muscle pains. Typically, the symptoms disappear 10–12 hours after the affected individual has left the building. Dirty air humidifiers, cooling towers and domestic water systems are also a favourite haunt of the "Legionella pneumophila" bacteria.

Fortunately things are not always that bad. Allergic reactions from fungal spores, pollen, house dust mites excretia, etc are far more widespread. House dust mites remain the most frequent source of allergy from indoor climate. Mites of 0.1–0.4 mm length live off human skin scales and dandruff, among other food sources. House mite populations ranging from minute numbers to several thousand per gram of dust are found in beds and other places of high humidity. Two to three per cent of the human population are allergic to the droppings of these mites, but far more will develop the allergy after long-term exposure.

The mildest form of nuisance from microorganisms in the indoor climate is obnoxious smells, especially from mould. Obnoxious smells can, however, be particularly disagreeable and difficult to remove.

Moisture

Experiments in climate chambers have proved that humans are poor in determining relative humidity in the 30–70%. Nuisance from the indoor climate in the form of dry mucous membranes, however, frequently arises. Unless the relative air humidity is very low (10–15%), these nuisances are not necessarily to be attributed to low air humidity, but more frequently to the effect of materials in the air which irritate the mucous membranes, eg organic solvent from building materials. Epidemiological investigations have shown that the frequency of colds increases with low air humidity (10). Conversely, the incidence of house dust mites, which is one of the most widespread causes of allergic illnesses, rises with increasing air humidity (11). A suitable compromise would be relative air humidity in the 30–50% interval. With higher air humidity indoors, furthermore, there is a growing risk of condensation on outside walls and windows, with damage to buildings and the formation of mould as a consequence.

A typical family of four produces approximately 10 litres of moisture per day by means of normal activities such as preparing food, washing clothes and washing up, and from the human beings themselves. Because of the high moisture production, air humidifiers are not normally required in houses. On the contrary, adequate ventilation must be provided, especially during food preparation, clothes washing and so on, so as to avoid too high a moisture content in the air. In office buildings the moisture content is somewhat lower and more dependent on the temperature of the outdoor air.

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