Indoor Air Quality

Source document:
SCHER (2008)

Summary & Details:
GreenFacts

Level 2 - Details on Indoor Air Quality

1. **Introduction – assessing health risks of indoor air pollution.....2**
2. **What are the main factors in indoor air quality?.....2**
3. **How can scientists determine whether indoor air pollutants pose a health risk?.....3**
4. **Are certain people more vulnerable than others to indoor air pollution?.....4**
5. **Why are the combined effects of indoor air pollutants hard to measure?.....5**
6. **Which chemicals found in indoor air are causing the most concern?.....6**
7. **What household chemicals and products can pollute indoor air? 7**
8. **Why is dampness in buildings a health concern?.....8**
9. **What kind of research on indoor air quality is needed? 9**
   - 9.1 How much information on indoor air quality is available today?.....9
   - 9.2 What questions about human exposure need to be answered?.....9
   - 9.3 What research is needed regarding health effects of indoor air pollutants?.....10
   - 9.4 Are existing measurement standards for indoor air quality adequate?.....10
10. **Conclusions and recommendations 10**

The answers to these questions are a faithful summary of the scientific opinion produced in 2008 by the Scientific Committee on Health and Environmental Risks (SCHER):
"Opinion on risk assessment on indoor air quality"

The full publication is available at: https://copublications.greenfacts.org/en/indoor-air-pollution/
and at: http://ec.europa.eu/health/opinions/en/indoor-air-pollution/

This PDF Document is the Level 2 of a GreenFacts Co-Publication. GreenFacts Co-Publications are published in several languages as questions and answers, in a copyrighted user-friendly Three-Level Structure of increasing detail:

- Each question is answered in Level 1 with a short summary.
- These answers are developed in more detail in Level 2.
- Level 3 consists of the Source document, the internationally recognised scientific opinion which is faithfully summarised in Level 2 and further in Level 1.

All GreenFacts Co-Publications are available at: https://copublications.greenfacts.org/
and at: http://ec.europa.eu/health/scientific_committees/policy/opinions_plain_language/index_en.htm

1. Introduction – assessing health risks of indoor air pollution


Several household cleaning products emit chemicals.
Source: Sanja Gjenero

Air pollution can cause health problems such as respiratory diseases (e.g. asthma), allergies, and possibly lung cancer. It is one of the major environmental health concerns for Europe and the goal of the EU air policy is to achieve levels of air quality that do not result in unacceptable risks to human health.

Much progress has been made in tackling outdoor air pollutants. Indeed, outdoor air quality is monitored across Europe and limit values have been adopted for the concentration of the most common pollutants in outdoor air. However, when dealing with air pollution it is important to consider both outdoor and indoor air.

Some indoor air pollutants come from the outside air, but most are released inside the home, for example through the use of cleaning products, air fresheners, pesticides and fuel for cooking and heating. Emissions from construction materials and furniture are another common source of indoor air pollutants. Micro-organisms, such as fungi that release spores, may also contaminate indoor air and induce allergies and asthma.

Global trends such as climate change and soaring energy costs can impact indoor air quality. For example, extreme weather conditions may increase the need for additional thermal insulation and decreased ventilation, which may lead to too high or too low indoor temperatures or to humidity problems.

Evaluating and managing the health risks of indoor air pollution in Europe is complex. A wide variety of pollutants, exposure levels and possible health effects must be considered, along with differences in cultural habits, lifestyles and climate. Also, some people – such as children, pregnant women and the elderly – may be more vulnerable than others.

This opinion aims to provide a scientific basis for assessing the risks to human health linked to indoor air quality and for policy making. It considers how these risks are currently evaluated and how they should be assessed in the future, including in the case of simultaneous exposure to multiple pollutants. It covers indoor environments where the general public may be exposed to pollutants (such as homes, offices, schools, and closed vehicles), with a particular focus on vulnerable groups of population such as children, pregnant women and elderly people. It does not address how to reduce or prevent adverse health effects, nor does it **c**over industrial exposure or active smoking.

2. What are the main factors in indoor air quality?


Pets and pests are sources of allergens
Credit: Katya Foldvaryove

The main factors that determine indoor air quality are:

- **Chemicals:** Two common causes of complaint regarding poor indoor air quality are bad smells and irritation of the eyes, nose and throat. Such irritation may be induced by specific chemicals, but also by factors such as dry air. Bad smells are not harmful in themselves but may cause unpleasant effects and increase symptoms such as headache, nausea, and irritation of eyes or throat. The hazards associated with chemicals and their effects on health are not always well known, particularly for long term exposures.

- **Radon:** Radon is a gas that occurs naturally in soil and rock in some regions and that can get inside buildings by diffusing through the soil. In indoor air, it can lead to lung cancer.
- **Suspended particles:** Coarse, fine and ultrafine particles in ambient air are known to cause adverse health effects, including on the respiratory and cardiovascular systems. Particles may in part come from outdoor pollution, but can also form indoors by the burning of fuels for heating and cooking, and by reactions between ozone and some volatile organic compounds (VOCs). In addition, man-made nanoparticles, that are increasingly used in consumer products, may have an impact as indoor air pollutants.
- **Microbes:** Microorganisms such as fungi and viruses may play a role in the development of asthma and allergies involving the airways. This is for instance a problem in damp buildings or indoor environments where there is mould because many fungi release substances that cause allergies. Virus infections may also be transmitted by indoor air and some of them can lead to an increase in asthma and allergies.
- **Pets and pests:** Indoors, pests, house dust mites, cockroaches, and – in inner cities in particular – mice are important sources of allergens. These allergens can lead to diseases of the airways, rhinitis, and asthma. Exposure varies depending on the type of environment and cultural habits. How much contact with pets affects the development of asthma in people remains unclear. However, allergic people should avoid exposure to substances to which they are allergic.
- **Humidity:** There is an optimal level of humidity in indoor air. Too low humidity causes eye irritation, dry skin, and rashes, whereas too high humidity results in water damage and mould problems and favours the growth of dust mites.
- **Ventilation**: It is one of the most important factors determining indoor air quality. Poorly aired offices and schools, for instance can affect health and work or academic performance. Controlled ventilation is especially needed in heavily insulated buildings that allow little air exchange with the outside.

- **Temperature:** As well as causing discomfort, indoor air that is very cold or hot is highly unhealthy. Air that is too warm, for example, aggravates the effects of insufficient humidity.

3. How can scientists determine whether indoor air pollutants pose a health risk?

To determine the potential of a pollutant to cause health effects, it is necessary to consider several factors:

- **Toxicity of pollutants and their concentrations in indoor air.** Indoor air may contain more than 900 different organic compounds in addition to particles, microbes, and allergens. These pollutants are emitted during cooking, cleaning, and heating and from other sources such as building materials. The concentrations of pollutants in indoor air depend on the types of pollutants, the rate at which they are emitted, how they are taken up by different materials and how much the interior is ventilated. Cultural habits may also be an important factor determining indoor air quality.
- **Exposure.** People can be exposed to pollutants directly by breathing them in, and indirectly by ingesting them, so all possible routes of exposure should be considered. Exposure to dust, for example, can entail exposure to other, less volatile pollutants that stick to dust particles. Young children may ingest more dust than they breathe in, because they spend more time on the floor and put their hands in their mouths. Dust particles are relatively large and do not stay suspended in the air for long. When assessing exposure it is important not to neglect a possible impact of compounds that are present in low concentrations but are very toxic, or of compounds which are difficult to detect. Assessments

should use realistic exposure scenarios. Since exposures can vary tremendously, the whole exposure range, including the exposures of the most sensitive and most exposed subgroups, should be considered and not only average or median values.

- **Exposure-response relationship.** To assess the risk posed by any substance, it is crucial to know how the body responds to different amounts of the substance, both in the short and long term. To evaluate local health effects such as irritation of the nose, skin or eyes, the concentration of pollutants in the air provides relevant information about exposure. However, to assess the effects of a pollutant in the body as a whole, it is necessary to calculate how much of the substance gets inside the body, for instance taking into account breathing volumes, and how much stays in the alveoli or is eliminated when breathing out. To determine whether pollutants pose a health risk and cause illness, scientists sometimes use data on the health of people who have been exposed to pollutants at work. When using these data to draw conclusions it is necessary to consider in the calculations that people usually spend a lot more time at home than at work. It is also important to realize that these results are representative of the working population and may not be directly applicable to the general public.
- **Risk characterisation.** In the final step of the risk assessment process, all the collected scientific evidence is analysed to determine the probability that a specific pollutant will cause illness.

In some cases, particularly those involving microbes, it is difficult to establish a direct link between a particular agent and a health effect. In those cases the apparent association may be strengthened by eliminating confounding factors.

For some indoor air pollutants, national and international guidelines or limits of exposure have been set, based on known health effects.

4. Are certain people more vulnerable than others to indoor air pollution?

Certain groups are potentially more vulnerable than others to indoor air pollution. These include children, pregnant women, people over 65 years of age, and persons suffering from cardiovascular and respiratory diseases (e.g. asthma). Other factors that may render some people more vulnerable are genetic traits, lifestyle, nutrition and – for some pollutants – other health problems (e.g. immunodeficiency).


Some people are more vulnerable than others to indoor air pollution
Credit: Stephan Czuratis

Depending on their age and on the chemical substance to which they are exposed, **children** may be more vulnerable than adults to certain toxic substances. They are more vulnerable than adults to lead and tobacco smoke, and perhaps also to phosphorous-containing pesticides. Studies on outdoor air show that pollutants may disrupt the proper development of the lungs in foetuses and young children. This effect on child lung development has been observed at a level at which no adverse effects are seen in adults, which suggests that children are more vulnerable than adults. In addition, air pollutants may cause cough, bronchitis and other respiratory diseases, and make asthma worse – though it is difficult to determine exactly which pollutants are responsible for a given effect. Particulate matter, nitrogen dioxide and ozone are likely to be important causes.

Elderly people may be particularly vulnerable to air pollution because the ability to eliminate chemicals from the body decreases with age. However, they may also be less sensitive to some effects such as irritation of the eyes and nose.

Persons suffering from **cardiovascular diseases** are more vulnerable to particles and those suffering from **respiratory diseases** such as asthma are more vulnerable to several air pollutants.

At present, several studies are investigating how pollutants affect different groups of people. This research should help identify vulnerable populations.

It is recommended that science-based health risk assessments always take into account vulnerable groups and that each case be considered separately.

5. Why are the combined effects of indoor air pollutants hard to measure?

Indoor air is a complex mixture of pollutants (chemical substances, allergens and microbes) from various sources that changes with time. At present, however, relevant data and established methods to evaluate the health effects of such mixture of air pollutants are rare and risk assessments of air pollution mostly deal with exposure to single substances. In addition, the few findings available on interactions among more than two chemicals usually do not address issues of long-term toxicity at realistic concentrations.

Data from studies on individual chemicals can be used directly if the components of the mixture act independently. However, some of the chemicals in the air may influence each other. Indeed, several chemicals acting together may cause more (or less) harmful effects than the sum of the effects caused by each chemical separately. For example, potentially harmful combined effects of mixtures of pesticides have been observed at concentrations of each single component at which, individually, they do not affect health. In these cases, data from exposure to single chemicals cannot be used directly to determine health risks.

A number of studies have dealt with the combined effects of indoor air pollutants, including effects of fine particles and gases in ambient air. For example, particles in the air may help some pollutants reach the deeper parts of the lungs (bronchioles, alveoli), so exposure to particulate matter could enhance the allergic responses of susceptible individuals. In asthmatics, nitrogen dioxide increases the inflammatory effect of exposure to allergens in the air.

There is no generally accepted strategy for evaluating health risks from exposure to a mixture of pollutants. The approach consisting in adding up the doses of the individual pollutants can be useful for some mixtures of chemicals. In other cases, it is possible to use data from the combined effects of two chemicals and extrapolate the results to more complicated mixtures. In general however, there are not enough relevant results on the mechanisms of actions to estimate the toxicity of a chemical mixture, and the available methods used may not be adequate.

Risk assessments which take into account the combined exposure and cumulative effects of the pollutants in indoor environments are seldom possible. However, the possibility of combined effects should be considered in the risk assessment and evaluated case-by-case. Interactions between chemicals and other factors such as microbes are insufficiently known to provide guidance.

6. Which chemicals found in indoor air are causing the most concern?


Tobacco Smoke contains several types of harmful pollutants
Credit: Vildan Uysal

Ranking air pollutants by risk is difficult because indoor air contains a large number of different substances and because levels vary widely across Europe. Nonetheless, those that raise highest concern because of the adverse health effects they have caused or have a high potential to cause are:

- **carbon monoxide (CO)**
- **formaldehyde (H_2CO)**
- **benzene (C_6H_6)**
- **nitrogen dioxide (NO_2)**
- **naphthalene ($C_{10}H_8$)**.

Other pollutants that are of concern in indoor air are:

Environmental tobacco smoke – Tobacco smoking is the primary source of several indoor emissions (benzene, fine and ultrafine particles) and associated health effects. In adults, secondhand tobacco smoke is linked with irritation and coronary heart disease, and it seems to make respiratory symptoms worse. In children, it appears to be linked with sudden death syndrome and middle ear infections.

Radon (Rn) – Radon is a gas that emanates naturally from the ground, particularly in areas where bedrock contains uranium in excess. It can get inside buildings by diffusing through the soil and is a problem in many parts of Europe. Its presence in indoor air can lead to lung cancer.

Lead (Pb) – The use of lead-containing pigments in indoor paints has been banned or restricted. However, some old houses in parts of the EU still have paintwork containing lead. Even low level exposure to lead is harmful for children, for whom the main route of exposure is swallowing dust.

Organophosphate pesticides – These pesticides which are used indoors against insects, are applied to cracks and crevices or present in insect strips. In some studies, they have been shown to affect the development of the nervous system, which raises concern for possible effects on children. Indeed, indoor exposure to these compounds can be high and occurs through inhalation or ingestion due to accumulation on surfaces, including on children's toys, and in dust. Concentrations in indoor air are unlikely to be high enough to cause short-term effects, but they may contribute considerably to the overall uptake of these pesticides by children.

Other indoor air pollutants that have been studied are volatile organic compounds (VOCs) and phthalates.

Volatile organic compounds (VOCs) are emitted by many consumer products and decomposing materials. Three of the most worrisome are formaldehyde, benzene, and naphthalene.

The total amount of VOCs may serve as a very general indicator of indoor air quality. Because VOCs mixtures can vary a lot in composition, total VOCs are not a useful measure for risk assessment.

Some volatile organic compounds may react with ozone to produce secondary pollutants, including fine and ultrafine particles. Some of these secondary pollutants cause irritation and poor perceived air quality at concentrations that can be found in indoor air. Altogether,

the concentrations of VOCs and ozone causing mixture effects are as yet poorly known and evidence of health effects at common indoor concentrations is inconclusive.

Air pollutants can be emitted from intact materials in the indoor environment. In addition, when some materials decompose, they can form and release new compounds. These should be identified and their potential health effects evaluated.

Phthalates are common contaminants in the indoor environment. High exposure to phthalates is linked to asthma and rhinitis. However, it is very unlikely that the low exposure levels of phthalates by inhalation in indoor air will have any harmful effects. From the scientific evidence available, the SCHER does not consider phthalates as high concern chemicals in indoor air.

7. What household chemicals and products can pollute indoor air?


Certain paints emit chemicals
Credit: Daniel Case

There are many different household consumer products, including detergents, floor care products, furniture and household fabrics, disinfectants, air fresheners, products for laundering, glues, paints, paint strippers and personal care products. These products may emit chemical compounds or particles that can be breathed in, either when the liquids that contain them evaporate, when they are sprayed as aerosols or when candles and incense are burned. Very little is known about the concentrations that these emissions reach in indoor air, or how much they contribute to total exposure. In addition, consumer products, their use and the concentration of emissions from these products in indoor areas may be very different across the EU.

A Danish study assessing indoor air pollution by various consumer products found that many of them emitted volatile and semi-volatile organic compounds (VOCs and SVOCs). Using computer models and assumptions of different products being present in different rooms, children's rooms were predicted to contain higher concentrations of these compounds than kitchen/family rooms, and halls/utility rooms. Although typical levels were in most cases acceptable, worst case exposures for some of the compounds exceeded accepted limits. The worst emitters of the investigated consumer products were incense and spray paint, printed matter, and electronic equipment.

VOCs from consumer products may contribute on average to 10-20 % of total VOCs in different indoor environments. This represents roughly a similar fraction as transport from outdoors, depending on the quality of the outdoor air. Air fresheners, general purpose cleaners and floor care products have been estimated to be major sources of VOC emissions among household products. In some studies, professional domestic cleaning has been associated with asthma or asthma symptoms. From the rare epidemiological studies evaluating the potential health effects of consumer products, it is not possible to determine whether the products are the cause of the effects because there are many other factors that might contribute as well.

8. Why is dampness in buildings a health concern?


Humidity promotes the growth of moulds
Credit: Infrogmation

Adverse health effects associated with building dampness and moisture problems have been reported since the 1980s but are still a poorly understood phenomenon.

Dampness or moisture may accumulate into the building structures or finishing materials through leaks or due to condensation as a result of insufficient ventilation or faulty construction. Moisture from the ground may also penetrate into the building.

Excess water stimulates the growth of moulds which emit many different compounds and particles into the air. Dampness and moisture may also cause materials to start breaking up chemically, and to release compounds as they degrade. Inadequate ventilation may increase the level of these compounds in indoor air.

The microbes that grow in various dampness situations vary and not all dampness is equally harmful. It is also likely that people differ greatly in how sensitive they are to damp indoor environments.

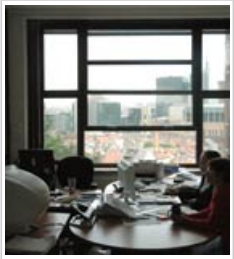
There are many types of emission from a microbial growth e.g., particles including spores, vegetative cells and submicron-size fragments and toxins. Volatile organic compounds emitted from microbial growth include those that are known as odour of mould.

Many epidemiological studies have shown a link between building dampness and adverse health effects. The larger the extent of the damage caused by humidity in the building, the worse the health effects. These effects range from irritation of mucous membranes, respiratory symptoms and infections, to chronic diseases, such as asthma and allergy. General symptoms, such as fever, fatigue, headache and difficulty to concentrate have also been reported, and clusters of cases of other diseases have also been associated with indoor dampness. However, it is still not known precisely how dampness intervenes in the appearance of these symptoms and which are the main substances responsible. Studies indicate that renovating the building either decreases or eliminates the symptoms.

Adverse health effects associated with building dampness and moisture are a concern. Dampness and moisture problems in buildings are common in countries where comprehensive studies have been done, and are likely to be an underestimated indoor air problem in EU. However, further research is needed to assess how serious or widespread this problem is at EU level.

9. What kind of research on indoor air quality is needed?

9.1 How much information on indoor air quality is available today?


It is necessary to investigate how people are exposed to pollutants in indoor air

The chemicals and particles present in indoor air and their concentrations vary greatly across different indoor spaces and in different EU countries. The data for risk assessment are scarce and often insufficient to account for all the variability and complexity in the indoor environment.

Information is available on the levels in indoor air of some well-known pollutants (such as carbon monoxide, nitrogen oxides, VOCs, etc.) in Europe. These data help identify the compounds with highest concentrations and of greatest concern. Effects and risks for most of these "usual" pollutants are known so it is possible to create strategies to mitigate their impact. However, new sources of pollutants have emerged (such as VOCs from air fresheners) and some of them may react to produce secondary pollutants whose effects are unclear.

At present, outdoor air quality is monitored for some pollutants (e.g. particulate matter, nitrogen oxide, ozone) but the data cannot be extrapolated to predict the concentrations that reach the inside of buildings, because several local factors contribute to the access of pollutants indoors (e.g. tightness of the building). Instead, the levels of pollutants in indoor air also have to be measured, though this may be difficult to do in a systematic way in private spaces. To help risk assessment it is also necessary to monitor other factors such as the ventilation rate, the level of carbon dioxide, general cleanliness and signs of dampness.

Guideline values should be provided for key pollutants as well as guidance on how to deal with them.

9.2 What questions about human exposure need to be answered?

The existing data on indoor air pollutants should be reviewed and the major air pollutants and their levels in each Member State of EU should be identified. It is a priority to compile a European-wide database that identifies data gaps and serves as background for future research.

Existing experiences and methods of doing risk assessments should be collected and organised.

The main research priorities are to:

- Investigate the variation of exposure to indoor air pollutants; identify which factors that can easily be measured could serve as indicators of the exposure of an individual.
- Identify the main sources of pollutants in indoor environment and quantify how much each source contributes to total concentrations in indoor air.
- Measure the emission levels of chemicals from consumer products in realistic use situations.
- Obtain information on harmful emissions in water-damaged buildings, such as toxic compounds released when building materials decompose.

Moreover it is recommended to:

- Identify, evaluate, verify and harmonize models that are currently used to predict the sources and the fate of indoor air pollutants.
- Evaluate potentially harmful emissions from indoor combustion processes.

9.3 What research is needed regarding health effects of indoor air pollutants?

As far as health effects of indoor air pollutants are concerned, it is a high priority to increase research on:

- Effects due to exposure to mixtures of indoor air pollutants and methods for their evaluation.
- Adverse health effects of microbes and biological aerosols, especially those affecting other organs than the respiratory tract.
- The contribution of indoor air pollutants to childhood respiratory diseases.
- The exposure-response relationships, especially in vulnerable groups.

Moreover, research is needed on:

- Effects and risks of products which emit indoor air pollutants that can react in indoor air.
- Possible effects and risks of man-made nanoparticles in indoor air.
- The contribution of coarse, fine and ultrafine particles from indoor sources to adverse health effects.
- Persons suffering symptoms in buildings damaged by humidity.

9.4 Are existing measurement standards for indoor air quality adequate?

The development of new measurement standards for indoor air quality are not a high priority, but existing ones should be validated and harmonized, in particular those concerned with indoor emissions from building materials and with biological agents.

Some of the measurement methods developed for outdoor air quality can also be applied to many indoor environments. In workplaces however, methods are often developed for higher concentrations of pollutants.

10. Conclusions and recommendations

Assessing the health risks of indoor air pollution is very difficult as indoor air may contain over 900 different chemicals, particles and biological materials with potential health effects.

Also, many different factors influence air quality, for example ventilation, cleaning conditions, properties of buildings, products used in households, cultural habits, climate and outdoor environment. Therefore, large variations in indoor environments can be expected across the EU.

The European Commission Scientific Committee on Health and Environmental Risks (SCHER) concludes the following:

- The principles used in the EU for risk assessment of chemicals should also be applied to health risk assessment of pollutants in indoor environments.
- The information available to assess the risk of indoor air is in general limited. More data are needed, particularly on health effects of particles and microbes, levels of exposure, and effects of indoor pollutants on vulnerable populations.

Several gaps in knowledge have been identified (see Question 9) and should be addressed by European-wide multidisciplinary research.

- Carbon monoxide, formaldehyde, benzene, nitrogen oxides and naphthalene are compounds of particular concern because they have caused adverse health effects as indoor pollutants or have a high potential to do so. Environmental tobacco smoke, radon, lead and organophosphates are also of concern.
- Data on true exposure to volatile organic compounds emitted by numerous consumer products is insufficient to establish a link with possible health effects because of the many confounding factors. Some of these emitted substances may react in air and on surfaces and produce secondary pollutants such as fine and ultrafine particles whose health effects are poorly understood.
- More research is needed to understand how humidity and mould problems in buildings can affect health and to evaluate the seriousness of the problem in EU countries.

The SCHER also recommends the following:

- Gathering more data on combined effects of indoor pollutants, which are so far limited.
- Considering all possible routes of exposure (through inhalation, ingestion, or through the skin) when assessing the risks.
- Developing health-based guideline values for key pollutants and other practical guidance in general to help risk management.
- Collecting and systematizing practical experiences to establish evidence-based risk assessment approaches.
- Considering the impact of indoor exposure when evaluating the health effects of outdoor air pollution, given that concentrations of air pollutants are usually higher indoors and that people tend to spend more time indoors.
- Evaluating all relevant sources known to contribute to indoor air pollution, such as tobacco smoke, candles and open fires, building materials, furniture, pets and pests, use of household products, and conditions that lead to the growth of moulds.