

POTENTIAL CHEMICALS IN THE INDOOR AIR¹

The main chemical pollutants that can be found in the indoor air are:

- Carbon dioxide (CO₂)
- Carbon monoxide (CO)
- Nitrogen dioxide (NO₂)
- Sulphur dioxide (SO₂)
- Volatile organic compounds (VOCs)
- Semi-volatile organic compounds (SVOCs)
- Heavy metals
- Ozone (O₃)
- Fine particulate matter (PM₁₀, PM_{2.5})
- Environmental tobacco smoke
- Asbestos

Carbon dioxide (CO₂)

Carbon dioxide is a colourless, odourless gas that is produced by the combustion of carbon, in human metabolic processes and in all combustion of carbon-based fuels (e.g. in motor vehicles).

Sources: In school classrooms, the single largest source of CO₂ is air breathed out. In concentrations of over 1.5% (15,000 PPM), it causes reduced concentration.

Effects on health: CO₂ has immediate and acute toxic effects on the respiratory system: in the case of periods of exposure of up to 15 minutes and atmospheric concentrations of up to 5%, CO₂ causes vasoconstriction and increased respiratory activity; in concentrations >10% it causes respiratory paralysis and fainting; in concentrations >25% it causes immediate death.

Carbon monoxide (CO)

Produced by the incomplete oxidation of carbon in combustion processes, carbon monoxide is a colourless, odourless gas.

Sources: Old or poorly maintained and managed combustion devices (e.g. boilers and ovens), or devices with an inadequate, obstructed or switched off exhaust or discharge system may emit carbon monoxide. Other sources include vehicle exhaust gases from garages, streets and parking places close to schools.

¹ Based on the Annex to the publication *Air Quality in Schools: Everybody's Duty, Children's Right*, produced by the SEARCH I project.

Effects on health: Carbon monoxide's toxicity is due to its greater affinity for bonding with haemoglobin (COHb) than oxygen, and the consequent reduction in the oxygen transported in the blood. Low concentrations of carbon monoxide in the air cause tiredness, as well as chest pain among those suffering from heart complaints; medium concentrations cause coordination problems, headaches, nausea and dizziness. Exposure to high concentrations can be fatal.

Nitrogen oxides (NO₂, NO)

Nitrogen oxides are toxic gases, and NO₂ is also a highly corrosive reactive oxidant.

Sources: The principal indoor sources are combustion processes (e.g. poorly functioning combustion appliances such as gas stoves, soldering and tobacco smoke). The principal outdoor sources are vehicles and other specific machinery for maintaining gardens and grounds.

Effects on health: Nitrogen dioxide acts can irritate the mucous of the eyes, nose, throat and airways. Exposure to high levels of NO₂ can cause pulmonary oedema and diffuse pulmonary lesions. Continued exposure to high levels of NO₂ can contribute to the development of acute or chronic bronchitis. Exposure to low levels of NO₂ can cause increased bronchial reactivity in some asthmatics and reduced pulmonary function in patients with chronic pulmonary obstructive diseases. It also increases the risk of respiratory infections, particularly in young children.

Sulphur dioxide (SO₂)

Sulphur dioxide (SO₂) is a colourless, water-soluble, irritant, non-flammable gas with a strong odour. It is derived from the oxidation of sulphur in the course of combustion processes of substances containing this element either as an impurity (in the case of fossil fuels) or as a core constituent. It tends to gather in lower areas, as it is heavier than air.

Sources: The primary natural sources are volcanoes, which contribute to maintaining the environmental level, while human-made sources include the combustion of solid (carbon) or liquid (petrol) fuels for domestic heating, to fuel vehicles, or for industrial purposes (plastic production, the desulphurisation of natural gases, pyrite furnaces and waste incineration). In indoor environments, as in the case of other products of the combustion process, concentrations depend on the presence of internal sources linked to the use of stoves, ovens, gas and kerosene heating appliances and tobacco smoke. Concentrations of SO₂ in confined environments are usually lower than those found in the air, both because SO₂ is absorbed into the surfaces of furnishings and hangings, and because it is neutralised by the ammonia present in indoor environments as a result of the presence of humans.

Effects on health: At low concentrations, the damage associated with exposure to SO₂ occurs mainly in the respiratory system (chronic bronchitis, asthma and tracheitis), skin and mucous membranes. Brief exposure to high concentrations can cause tachypnea, tachycardia and irritation of the eyes, nose and throat.

Volatile organic compounds (VOCs)

Volatile organic compounds are the range of liquid and gas substances with boiling points from 50–100°C to 240–260°C. The term “volatile” refers to the capacity of these chemical substances to evaporate easily at room temperature.

Indoor sources: VOCs are produced by cleaning, painting and other related products; pesticides, insecticides, disinfectants and detergents; glues and adhesives; human activities (tobacco smoke, cosmetics, personal care and hygiene products); furniture and materials; construction materials; printers and photocopiers.

Outdoor sources: VOCs can be found in industrial and vehicle emissions.

Effects on health: Exposure to VOCs can cause acute responses, which, depending on the concentrations involved, are manifested as irritation to the eyes, nose and throat, headaches, nausea, dizziness and asthma attacks. Exposure to high concentrations, on the other hand, can cause chronic conditions such as kidney or liver failure, damage to the central nervous system, and cancer.

The following VOCs are found most frequently in indoor environments:

Formaldehyde

Formaldehyde is a colourless gas with a characteristic strong odour that irritates the eyes and respiratory tract.

Principal sources: Formaldehyde can be found in wallpaper, chipboard, insulation, colourants, plastic materials, carpets, fabrics, detergents, preservatives, disinfectants and cigarette smoke.

Effects on health: As formaldehyde is extremely soluble in water, it can easily cause irritation to the mucous membranes through contact with them. It also affects the nose, throat, respiratory pathways, eyes and skin via contact. Exposure can also have neurological consequences, manifesting as tiredness, anxiety, migraines, nausea, drowsiness and dizziness. Acute intoxication mostly occurs as a result of accidental ingestion. Exposure to high concentrations can quickly result in death. Chronic intoxication mostly occurs as a result of inhalation or physical contact. Formaldehyde is a carcinogenic compound.

BTEX

Among VOCs, benzene, toluene and xylenes (BTEX) have been recognised as principal indoor air pollutants and have been ranked as the most frequently detected compounds in the indoor air. Their concentrations are generally higher in the indoor air than in the outdoor air. Elevated BTEX levels indoors can be caused by widely present indoor sources such as building materials, decoration and renovation materials, adhesives, solvents, cooking, environmental tobacco smoke (ETS) and outdoor air pollution.

Benzene

Benzene is an aromatic hydrocarbon present in products derived from coal and petrol. At room temperature it appears as a colourless liquid that can evaporate very quickly into the surrounding air. Like all VOCs it has a strong, sweet smell, which most people are able to detect at concentrations of between 1.5 and 4.7 PPM. It is a highly flammable substance, but its main threat comes from the fact that it is known to be highly carcinogenic to humans.

Indoor sources: Sources are cigarette smoke, the incomplete domestic combustion of coal or petrol, and fumes released by products containing benzene such as glues, paints, furniture wax and detergents.

Outdoor sources: Sources are exhaust fumes from motor vehicles and industrial emissions from the combustion of natural fuels.

Effects on health: Exposure to benzene occurs primarily through inhalation, but can also occur through physical contact with the skin, or ingestion.

Brief exposure to high concentrations (10,000–20,000 PPM) has acute toxic effects and can be fatal. Lower concentrations (700–3,000 PPM) can cause dizziness, drowsiness, increased heart rate, tremors, confusion and loss of consciousness.

More prolonged exposure to lower concentrations can cause memory problems and altered mental state.

Repeated exposure to concentrations of only a few PPM over a decade or more can cause cancer.

Toluene

Toluene is a non-corrosive, volatile liquid with an aromatic odour.

Toluene is added to gasoline, used to produce benzene, and used as a solvent in paints, coatings, synthetic fragrances, adhesives, inks and cleaning agents. It is also used in the production of the polymers used to make nylon, plastic soda bottles and polyurethanes, and for pharmaceuticals, dyes, cosmetic nail products, and the synthesis of organic chemicals.

Indoor sources: Sources are household products (paints, paint thinners, adhesives, synthetic fragrances and nail polish) and cigarette smoke.

Outdoor sources: Automobile emissions are the principal source of toluene in the ambient air. Toluene may also be released into the ambient air during the production, use and disposal of industrial and consumer products that contain toluene.

Effects on health: Acute exposure at levels above the maximum contaminant level (MCL) cause toxicity to the central nervous system.

Chronic exposure: Long-term exposure to toluene at levels above the MCL has the potential to cause the following health effects: spasms, tremors and imbalance; impairment of speech, hearing, vision, memory and coordination; and liver and kidney damage. In relation to the nervous system, it may cause fatigue, nausea, weakness and confusion.

Xylenes

Xylenes are extensively employed in a broad spectrum of applications, primarily and increasingly as a solvent, as they are a safe replacement for benzene, and also in gasoline. Xylenes are a component of BTEX (benzene-toluene-xylene) and are also frequently used in the rubber industry with other solvents such as toluene and benzene.

Indoor sources: Xylenes are used in products for household use, such as synthetic fragrances and paints.

Outdoor sources: Sources include emissions from industrial sources, vehicle exhausts, and volatilisation from solvents.

Health effects: Acute exposure at levels above the MCL can cause disturbances in the central nervous system, such as changes in cognitive abilities, balance, and coordination. Chronic exposure to levels of xylenes above the MCL has the potential to cause damage to the central nervous system, liver and kidneys.

Semi-volatile organic compounds (SVOCs)

Semi-volatile organic compounds (SVOCs) have higher vapour pressures than VOCs, are released as gas far more slowly from materials, and are likely to be transferred to humans by inhalation and by contact with particles attached to dust that may also be ingested (e.g. among infants and children putting their dirty hands in their mouths). Semi-volatile organic compounds are used in building

materials to provide flexibility (phthalates), water resistance or stain repellence (perfluorochemicals), as well as to inhibit ignition or the spread of flames (halogenated flame retardants). Environment and health concerns are emerging in relation to SVOCs that are considered to be endocrine-disrupting chemicals (EDCs). These include flame retardants, phthalates, pesticides, antimicrobials and polycyclic aromatic hydrocarbons.

Phthalates

Phthalates are used to make plastics such as polyvinyl chloride (PVC) more flexible and durable. Some phthalates are also used as solvents.

Indoor sources: Plastics that contain phthalates are commonly used in applications such as building materials (flooring, adhesives), clothing (raincoats), food packaging, toys, vinyl products and personal care products (cosmetics, perfumes, soaps, shampoos, hairsprays and nail polishes).

Effects on health: Some phthalates, generally those used to soften PVC, are endocrine disruptors. Exposure may also be via the inhalation of phthalates released into the indoor air from these materials.

Polychlorinated biphenyls (PCBs)

These chemicals belong to the broad family of chlorinated hydrocarbons. They were commonly used as insulators in electrical equipment as they have a high tolerance to heat, do not burn easily, and are non-explosive. In many countries their use is now banned. However, as long as PCBs do not leak from the light ballasts and potting materials (for insulation), they do not pose a health risk or an environmental hazard.

Indoor sources: PCBs have been used in hundreds of industrial and commercial applications, for example electrical, heat transfer and hydraulic equipment; as plasticisers in paints, plastics and rubber products; and in pigments, dyes and carbonless copy paper.

Effects on health: The long-term effects of PCB exposure include effects on the nervous and reproductive systems; immune system suppression; hormone disruption; respiratory tract symptoms; gastrointestinal symptoms; mild impacts on the liver; and impacts on the skin and eyes such as chloracne, skin rashes and eye irritation.

Flame retardants (Polybrominated diphenyl ethers [PBDEs])

These are widely used as they confer the ability to resist or inhibit the spread of fire in electronic products, foams and textiles.

Indoor sources: Sources include foam used in furniture, mattresses and car seats; plastics in electronics and wire/cable insulation; and textiles.

Effects on health: Halogenated flame retardants have been linked to thyroid disruption, reproductive and neurodevelopmental problems, immune suppression, and in some cases cancer in animal studies. In Europe, decabromodiphenyl ether (decaBDE), once used in the manufacture of electronics, was banned in July 2008.

Polycyclic aromatic hydrocarbons (PAH)

Polycyclic aromatic hydrocarbons are a broad range of (around 500) organic compounds comprising two or more rings of condensed benzene. Due to their lower levels of volatility, they are not considered to be VOCs — with a few exceptions (such as naphthalene) — but rather SVOCs. Those PAHs comprising three to five rings may be present in the atmosphere either as gases or as particles, while those characterised by five or more rings more often appear as solids. They are identifiable by their low level of solubility in water, their high capacity to bond with organic materials, and their high level of solubility in lipids and a number of organic solvents.

Sources: PAHs are predominantly found outdoors, mainly deriving from the combustion of fossil fuels and industrial processes. Other temporary sources are forest fires and campfires. Indoor sources include wood-burning fires, chimneys and cigarette smoke. Other indoor sources are the fumes from foods cooked over flames, smoked foods etc.

Effects on health: Toxic properties vary according to the spatial dispersal and number of condensed rings. Benzopyrene (BP) is the most regularly investigated, and information on the toxicity and abundance of PAHs often refers to this compound. These substances have carcinogenic effects.

Heavy metals

Heavy metals are a group of metallic elements extracted from mined ores that can be highly toxic in their elemental form or in compounds. The potentially toxic heavy metals include arsenic (As), copper (Cu), cadmium (Cd), lead (Pb), chromium (Cr), nickel (Ni), mercury (Hg) and zinc (Zn). Heavy metals are used as stabilisers in vinyl plastic materials, most notably wire insulation and other PVC products, and can be found in a variety of other uses in roofing, solder and radiation shielding, and in dyes for paints and textiles. Heavy metals bioaccumulate and often enter the water system. Human exposure is a concern.

Sources: **Mercury** can be found in thermostats, thermometers, switches and fluorescent lamps.

Chromium VI can be found in the chrome or stainless steel components of furniture. **Cadmium, cobalt, antimony trioxide** and other metals may be incorporated into paints, dyes and pigments, fabric, and some PVC products such as resilient flooring. **Lead** is a soft metal that has been widely used in the building materials industry. It can be found in house dust, indoor air, older lead-based paints and plumbing. It can also be found in art supplies, costume jewellery, leaded crystal, and the glazes on ceramics and pottery.

Effects on health: **Lead** is highly toxic, especially to young children. It can accumulate in human bones and organs and has been linked to anaemia and a number of developmental disorders. **Lead** and **mercury** are potent neurotoxins, particularly damaging to the brains of fetuses and growing children. The use of **lead** and **mercury** in the building industry has decreased significantly over the past 20 years, although **lead** continues to be used in some building materials. **Cadmium** is a carcinogen and can damage the kidneys and lungs. **Chromium VI** is listed by the International Agency for Research on Cancer (IARC) as a carcinogen. **Antimony trioxide**, used as a synergist in flame retardants, is classified as a carcinogen.

Ozone (O₃)

Ozone is a pale blue poisonous gas that is unstable and has a strong odour. It is present in layers of the atmosphere (in the stratosphere at a height of 15 to 60 km), but also in small quantities in the air we breathe (the troposphere). The ozone layer provides protection from ultraviolet solar radiation. The ozone present in the troposphere, however, contributes to air pollution and is poisonous to people and the environment. Ozone present in the lower atmosphere is produced by reactions that

take place in sunlight, involving nitrogen oxides and volatile organic substances, which, for these reasons, are referred to as the “precursors” of tropospheric ozone in the presence of solar radiation. Ozone is therefore considered a pollutant of concern, above all in summer in Mediterranean Europe when conditions are favourable for its formation (strong sunlight, scarce ventilation).

Sources: Indoor sources of ozone mainly comprise equipment operating at high voltages or using ultra-violet rays such as photocopiers, laser printers or ultraviolet lights, but they also include some types of air purifiers. In the absence of specific indoor sources, and under normal ventilation conditions, the main source of indoor ozone is the entry of air from the outdoors.

Effects on health: Exposure to ozone does not occur through ingestion or absorption via the skin, since ozone’s chemical reactivity is so high that its half-life as a solid or a liquid is negligible. Exposure among humans takes place through inhalation. Absorption through the nose or mouth are the most common and account for around 30% to 40% of inhalation, although 20% of inhaled O₃ is removed in the upper airways.

As a powerful antioxidant, O₃ reacts with many cellular component and biological materials in low concentrations and can cause a variety of reactions in different individuals. The most common symptoms of exposure are coughing, irritation of the throat, pain upon deep inhalation, pain behind the chest, headaches and nausea, while exposure can also cause bronchial hyperactivity.

Short-term effects include the increased reactivity of the airways, inflammation of the airways, reduced respiratory function, aggravation of existing pathologies such as asthma, increased hospitalisations for respiratory problems and increased fatality rates. In low concentrations, exposure to O₃ results in tiredness, headaches and reduced breathing capacity, while at higher concentrations it can cause coughing and irritation of the mucous membranes.

Fine particulate matter (PM_{2.5})

Particulate matter, or PM_{2.5}, is a component of diesel motor exhausts. The particles have a dimension of less than 2.5 microns in diameter. They can consist of a droplet of solid or liquid containing residues of various types.

Sources: The main source is traffic, although in winter months the contribution of domestic heating installations should also be considered; cooking, the use of household detergents, housework and the presence of people also cause the re-suspension of course particles.

Effects on health: PM_{2.5} particles are associated with a range of serious health effects, including lung disease, asthma and other respiratory problems. Children are particularly susceptible to pollution with atmospheric particles. Fine particles pose the greatest health risk as they are able to pass through the nose and throat and penetrate the lungs. This has an irritant effect on the airways (asthma, chronic bronchitis, reduced pulmonary function, blockage of the alveoli etc.), heart problems and the possibility of immune system disorders, encouraging the onset of chronic illnesses such as greater sensitivity to allergens.

Environmental tobacco smoke

Exposure to environmental tobacco smoke (or passive smoking) refers to the inhalation of smoke breathed out by other people, produced during the combustion of tobacco-based products. It contains a “mainstream” component (approximately 50%), which refers to the smoke inhaled and exhaled by the smoker, while the other half is “sidestream” smoke, given off by the cigarette. Environmental tobacco smoke and sidestream and mainstream smoke contain a complex mixture of around 4,000 substances. These include more than 40 known or suspected carcinogens such as 4-aminobiphenyl, 2-naphthylamine, benzene, nickel and a range of polycyclic aromatic hydrocarbons

(PAHs) and nitrosamine. A number of irritants such as ammonia, nitrogen oxide, sulphur dioxide and several aldehydes are present, as well as cardiovascular intoxicants such as carbon monoxide, nicotine and some PAHs.

Sources: The only source of environmental tobacco smoke is the combustion of tobacco-based products. The only means of exposure is inhalation.

Effects on health: Active smoking is the main predictable cause of sickness and death throughout the western world. Passive smoking has been classified as a cause of cancer among non-smokers by the US Environmental Protection Agency and the International Agency for Research on Cancer.

Non-carcinogenic effects: There is a connection between environmental tobacco smoke and chronic respiratory symptoms or chronic pulmonary obstructive illnesses, including asthma. Smoke is responsible for a considerable proportion of childhood respiratory pathologies from otitis to asthma and bronchopulmonia.

Active smoking by pregnant women, or their exposure to passive smoke, causes a significant reduction in the baby's birth weight and is associated with sudden infant death syndrome (SIDS), the sudden, unexpected and inexplicable death of babies between birth and one year of age.

Cardiovascular effects: Environmental tobacco smoke can lead to a reduced ability to transport oxygen, causing reduced tolerance for exercise and ischemia, an increase in platelet activation, endothelial damage, altered levels of lipoproteins and the thickening of the arterial walls, which can cause atherosclerosis and, where there is increased platelet activation, thrombosis. Ischemia, atherosclerosis and thrombosis increase the risk of myocardial infarction and other severe cardiovascular effects.

Asbestos

Asbestos is a generic term used for a group of silicates (materials containing silicon) in the form of fibres that are resistant to heat, humidity and chemical agents. Its principal materials can be divided into two groups, depending on the structure of their crystals: amphibolic fibres (which are linear in shape and penetrate all the way into the pulmonary alveoli); and coiled fibres (structured in leaves or in layers and more easily intercepted by the bronchi and bronchioles).

Main sources: Asbestos was used widely in construction (in sheets or panels, pipes, cisterns and flues, to cover metal structures and beams, and in plaster, attic insulation panels and flooring made from vinyl-asbestos); in industry (in primary materials for many manufacturing processes and objects, thermal insulation for high-temperature industrial processes, and sound-dampening materials); in products for household use (hairdryers, ovens and stoves, irons, oven gloves, ironing boards, fire-starting elements, casing for the protection of heating appliances, boiler doors, and fire-retardant blankets); and in transport (rail, ship and bus caulking, brakes, flame-retardant screens and brake linings).

Effects on health: Health effects arising from asbestos are linked to its fibrous nature: the fibrous particles released are extremely fine and, when inhaled, can penetrate the pulmonary alveoli. They can also remain suspended in the air for extended periods. Exposure to asbestos fibres is associated with illnesses affecting the respiratory system (asbestosis, pulmonary carcinoma) and the serum membranes, mainly of the pleura and peritoneum (mesothelioma). These symptoms manifest themselves after several years of exposure: 10 to 15 years in the case of asbestosis; and 20 to 40 years in the case of pulmonary carcinoma and mesothelioma. According to the International Agency for Research on Cancer, asbestos is classified as a carcinogen.