

accelerated air velocity. Only in these cases are measurements potentially useful.

The irritant effect of MMMFs, which is occasionally the subject of debate, is linked to fibres larger than the WHO variety and only occurs if mineral-wool insulating materials have not been installed properly or the cladding has become damaged over time and there are visible fibrous dust deposits. According to Walker et al. [23], there are no health-related grounds for removing old MMMF insulating materials that have been properly installed.

Asbestos fibre dust poses much more of a hazard. If it is suspected that asbestos fibres have been released in the building in question, further investigation must be carried out using the customary procedures, as described at length in [24] for example. If necessary, a refurbishment plan must be drawn up in line with the requirements of the Asbestos Directive [21].

Tobacco smoke in indoor workplaces

Tobacco smoke in indoor air is classified as carcinogenic for humans. By law, employees are entitled to a smoke-free workplace. Section 5 (1) of the Arbeitsstättenverordnung (Ordinance on Workplaces) [25] states:

“Employers must take the measures necessary to ensure effective workplace protection for non-smoking employees against the health hazards of tobacco smoke.”

There are various ways of complying with the legal requirement to protect non-smokers. The most effective is to impose a universal ban on smoking throughout the building concerned. Once such a ban is in place, there is no longer any need to include tobacco smoke when investigating sources of air pollution.

The German statutory accident insurance institutions published a report in 2011 on the topic of tobacco smoke pollution in workplaces, including an in-depth review of exposure situations in indoor workplaces [26].

12.4.7 Phthalates

Phthalates continue to be manufactured on a large scale. Around 1 million tonnes are currently produced every year in Western Europe, roughly 90% of which is used for plasticising in polyvinyl chloride (PVC) production [27]. Indoor applications include plastic floor coverings, additives including additives in building materials such as concrete, coatings or sealants and in condensers, wallpapers and textiles. As phthalates can be used as solubilising agents, they can also be found in paints, varnishes, adhesives, cosmetics and personal care products.

Unusually high levels of butanol and/or 2-ethylhexanol detected in the VOC analysis can be an indication of increased phthalate concentrations since they can be released from dibutyl phthalate (DBP) and di(2-ethylhexyl)phthalate (DEHP) plasticisers by means of hydrolysis.

Usually DEHP dominates indoors and has been found at concentrations around the low $\mu\text{g}/\text{m}^3$ mark in the air in homes

examined in a number of studies [27]. The total phthalate content usually detected in house dust can be up to 1,000 mg/kg though this increasingly includes longer-chain phthalate substitutes, e.g. diisononyl phthalate, in addition to the main component, DEHP [28].

Due to their hormonal properties and toxicity to reproduction, phthalate plasticisers in dust in nurseries can be a particular problem. The average phthalate level in such dust is more than three times higher than that of dust in homes [29]. The main sources are furnishings made of soft PVC – for instance, PVC floors, vinyl wallpaper, gym mats, plastic tablecloths or imitation leather upholstery. By contrast, there has long been a ban, for example, on the use of phthalates in children’s toys, which used to be common.

The UBA has recommended nurseries not to buy soft PVC products so as to reduce phthalate levels. Instead, nurseries and parents should opt for products that do not contain any of the plasticisers listed as being “of high concern” [30]. Retailers and distributors must provide consumers with the relevant information on request. Parents and nurseries should take advantage of this right. The UBA has drawn up a template letter for contacting retailers to find out more [31].

12.4.8 Insecticides

Although insecticides, i.e. products for insect pest control, are primarily used in agriculture and forestry, they are also used extensively indoors for the following purposes:

- to preserve wood and protect fabric (e.g. permethrin in wool carpets);
- to provide mosquito protection (electric vaporisers and sprays);
- to protect plants against pests;
- to treat parasitic skin diseases in humans and animals; and
- to eliminate pests (e.g. cockroaches, silverfish) by means of decontamination.

The following categories of substance currently play a role in indoor applications:

- Pyrethroids

Pyrethroids serve as active ingredients in more than half of the insecticides used indoors. They go by various names, including permethrin, cypermethrin, cyfluthrin, deltamethrin, allethrin and tetramethrin. Recently, there has been much debate about their effect on human beings. The target organ for pyrethroids is the nervous system – both in insects and in warm-blooded animals. Incorrect handling can cause acute poisoning in humans but there is also some debate as to the possibility of the substances penetrating the skin. The chronic neurotoxic potential is deemed to be low. Unlike the natural product pyrethrum, pyrethroids are extremely persistent by virtue of their absorption capacity, low vapour pressure and

high photostability. As a result, rooms that have been subject to pyrethroid exposure may have to be decontaminated [32].

- Phosphoric esters

Another class of insecticides frequently found are phosphoric esters, also known as organophosphates. The main types found indoors are dichlorvos, chlorpyrifos and diazinon. They appear in various products, including many insecticides found in the home, most of which are sprayed or applied in powder form. Dichlorvos is commonly found in insect strips because its relatively high vapour pressure means that it is distributed evenly throughout the room. As a result of recent findings concerning the properties of this substance, it has been removed from the list of active ingredients permitted in plant protection products. All phosphoric esters have a high acute toxicity for warm-blooded animals. As with the pyrethroids, they attack the nervous system but their method of attack is to inhibit important enzymes that are involved in muscle control processes. They also inhibit the breakdown of a pyrethroid-cleaving enzyme, thus reinforcing the effect when phosphoric esters are used in combination with pyrethroids.

- Carbamates

Carbamates are not very widespread in insecticide products, apart from those used in agriculture. They work in much the same way as organophosphates though their effect is not quite as strong. The main type is propoxur, which is mostly used in combination with active ingredients from the other two categories mentioned.

All insecticides can be emitted into the indoor air even quite some time after they are applied. This is due to a variety of processes such as vaporisation, desorption or attachment to dust. In practice, they can pollute the air for anything from a few days (as in the case of pyrethrum) to several weeks (dichlorvos) and months or longer (deltamethrin, permethrin).

Since many insecticides accumulate in dust, analysing dust deposits can deliver important information about the substances that have been applied indoors and the doses used. For instance, samples are taken from the air, airborne dust, house dust and surfaces (swipe samples) in order to analyse indoor pyrethroid levels.

Special polyurethane foam filter heads are suitable for air sampling. The airborne dust is separated off onto a fibreglass filter. Household dust is collected using conventional vacuum cleaners; selected sieve fractions with an upper grain size of 2 mm or 63 µm are then examined. Swipe sampling involves a defined surface being wiped with a swipe material (usually cotton) containing a solvent.

12.4.9 Pentachlorophenol (PCP) and lindane wood preservatives

With their biocidal agents, chemical wood preservatives prevent damage to wood. A distinction is made between fungicides, which prevent wood being destroyed or discoloured by fungi, and insecticides for preventing wood damage caused by insects.

In terms of indoor air quality, the wood preservatives pentachlorophenol (PCP) and lindane play a particularly significant role especially due to their widespread use, toxic effects and emission patterns.

Pentachlorophenol (PCP)

Due to its wide spectrum of activity, PCP was used to combat bacteria, fungi, dry rot, algae, snails and insects. It was primarily used as a fungicide in wood preservatives but it was also used in the textile and leather industry, e.g. for marquees and tents. It was approved for large-scale indoor coating between the end of the 1960s and 1978. The substance used was almost always technical-grade PCP, contaminated with dioxins and furans. The contamination levels reached up to 0.3%.

Following a ban on indoor PCP use in 1986, production of PCPs was banned in former West Germany in 1989 [33].

Lindane

PCP's significance as a fungicide was matched by lindane's as an insecticide wood preservative. Since 1983, at least 99% of the content of lindane has been γ -hexachlorocyclohexane – an effective insecticide. Lindane used to be the most commonly used insecticide in chemical wood protection, but substitutes such as pyrethroids (see Section 12.4.8) have largely taken its place.

Lindane was usually combined with PCP (see above) or dichlorodiphenyltrichloroethane (DDT). In the German Democratic Republic, the lindane/DDT mixture was used under the name "hylotox 59" up until 1988, especially in attics and sometimes in indoor rooms. Remaining supplies of hylotox products were allowed to be used until the end of June 1991. Since September 2006, there has been an EU-wide ban on the use of lindane indoors [35].

The active ingredients in the wood preservatives are emitted from the treated materials over a period of several years. Consequently, like many of the insecticides described in Section 12.4.8, they can be detected in many indoor rooms. An effective approach is to examine the treated materials and the house dust as well as taking air samples.

Investigation

To determine the level of pollution from wood preservatives, it is first necessary to establish when and how the wood preservative in question was used and in what quantity. Based on the PCP Directive [35], the following steps are then taken:

- If the investigation reveals that no PCP wood preservatives have been used, no further action is necessary.
- If there are grounds to suspect that PCP wood preservatives have been used, the first step, notwithstanding the PCP Directive, is to calculate the quotient of the treated wood surface and the room volume. Further action is only required if the quotient is $> 0.2 \text{ m}^2/\text{m}^3$.