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Announcement of the German Environment Agency

Conversion of industrial buildings into housing space: What needs to be considered with regard to possible pollutants in the indoor air?

Communication of the Commission on Indoor Air Hygiene (IRK)

Abstract

The conversion of industrial buildings into residential space requires special consideration of the inherited building fabric and associated pollutants. Due to the previous industrial use at contaminated sites, certain pollutants may play a significant role that are normally not the focus of refurbishments activities of residential spaces. In order to comply with the increased requirements with respect to indoor air quality in residential spaces, and to avoid unnecessary efforts and costs of amendments to the refurbishment, the Indoor Air Hygiene Commission (IRK) provides advice on how to prepare the conversion commercial buildings so that healthy living conditions are ensured.

Keywords: Indoor air quality, building renovation, hazardous substances, PAH, PCB

Introduction

In many regions, housing space is becoming increasingly scarce, which is reflected in rising property prices and rents. Meanwhile it can be assumed that the demand for office space in particular will likely decrease in the future due to new work models (“home office”; work from home). In addition, production sites in city centres are frequently being abandoned and relocated to the periphery. The conversion of industrial buildings into residential property therefore represents an opportunity to create new housing space through conversion without taking up additional space.

Studies by the German Federal Office for Building and Regional Planning [1, 2] have shown that “*the conversion of non-residential buildings into residential space is a suitable instrument to relieve the tight housing market in prospering cities. Conversions offer the opportunity to increase the supply of inner-city flats in densely populated areas with limited availability of space. In shrinking regions, conversion projects in attractive locations fulfil the demand for higher-quality living space.*” Reusing existing buildings instead of demolishing them also helps to minimise waste and protect resources and climate.

One imponderable that should not be underestimated when converting industrial or commercial properties for use as residential buildings are the associated higher-level requirements on indoor air quality due to the new use of the building in conjunction with possible previous contamination of the building fabric. Known hazardous substances such as asbestos and (so-called old) artificial mineral fibres, formaldehyde, wood preservatives, polycyclic aromatic hydrocarbons (PAHs), polychlorinated

biphenyls (PCBs) and volatile organic compounds (VOCs) may be contained in the building fabric or in furnishing materials. In addition, substances and operating materials that were used in the original utilisation of the building, such as heavy metals, halogenated volatile hydrocarbons (HFCs), mineral oil hydrocarbons (MKW) and pesticides, must also be taken into consideration. Building regulations only very occasionally provide binding specifications regarding the handling of such hazardous substances. When converting an industrial/commercial use into a residential use, typical hazardous substances for commercial sites come into consideration. These are summarised in **Appendix B**. In addition, one may find contaminations from industrial accidents and fire incidents, as well as possible contamination of the building fabric with biological substances such as pigeon and rodent droppings, carcasses, mould or endotoxins.

Energy-efficient refurbishment measures are necessary when converting production facilities. The removal of doors and the installation of sealed doors and windows can significantly reduce the air exchange in the building. This can lead to an impairment of indoor air quality and odour nuisance as well as impair health and well-being, especially if contaminated components are not subjected to pollutant remediation and remain within the energy-efficient, tighter building envelope. The quality of the indoor air in a specific building can be evaluated and assessed using the indoor guideline and guide values of the Federal Environment Agency's Committee for Indoor Guide Values (AIR)[1].

Outgassing from operating resources and equipment such as lubricants or chemicals that have penetrated the building fabric or the subsoil can often remain unidentified in the building without thorough testing and identification. In addition, the new uses (e.g. residential or office buildings) put higher requirements on indoor hygiene in place. For example, an odour of machine oil in a production hall may be accepted by employees because the such an odour is expected and can be explained to the users. In a residential or office space, such odours may not be acceptable and lead to complaints.

The approach described in this paper is limited to the issues that can have a significant impact on indoor air quality and therefore on the health of future building users. Other essential features and services related to the building that might also be relevant for future users, such as sound insulation, fire protection, accessibility or thermal insulation, are not addressed in this paper.

Our statement also focuses on possible hazards emerging from the building fabric. Regardless of this, possibly contaminated soil should be considered when re-utilising former commercial properties. In Germany, the “lower soil protection authority”, usually located in the environmental administration of the district, maintains a so-called register of contaminated sites or a register of suspected contaminated sites. If there is a legitimate interest, the authority is obliged to provide information.

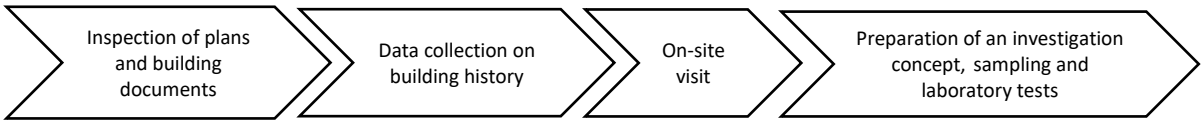
In addition to officially identified contaminated sites, the former industrial and/or commercial operations may have introduced pollutants into the soil and groundwater whose fate in the soil has not yet been investigated and assessed. Before conversion, it is advised to determine whether pollutants could have been penetrated into the soil and groundwater by previous operations. (A previous industrial or commercial use of a property usually justifies an initial suspicion). One can start with research or interviews that do not require any technical investigations on the property and help to verify the initial suspicion. The authorities have extensive knowledge of industry-related pollutants, entry points and typical damage patterns and risks. If the initial suspicion cannot be dispelled by the research, tests should be carried out to check whether there is any accumulation of hazardous substances in the soil. It should also be noted that the change of use from commercial property to residential building may also result in the conversion of open land areas into garden and play areas. For the assessment of pollutants in soils, the Federal Soil Protection Ordinance (BBodSchV) contains corresponding test and action values for pollutants for various uses of the soil.

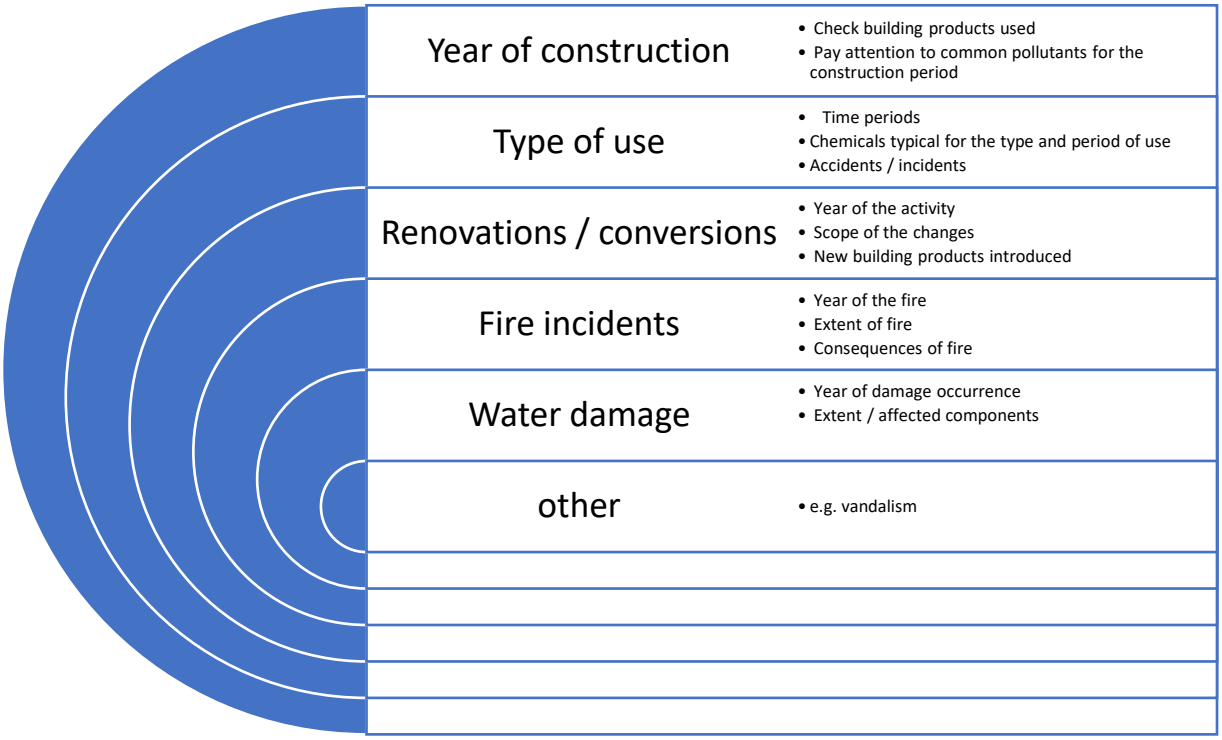
[1] https://www.umweltbundesamt.de/en/topics/health/commissions-working-groups/german-committee-on-indoor-air-guide-values, Access: Nov 10, 2023.

In addition, precautionary values from the BBodSchV can also be used as a guideline for a healthy living environment.

Inventory

If the conversion of a commercial building into a residential building is being considered, a thorough investigation should be carried out in advance. The following procedure is recommended:





Inspection of plans and building documents

If design, authorisation and construction plans are still available, these can provide worthwhile indications which parts of the building might contain hazardous substances. Building permits and notices from the authorities may, for example, mention fire compartments or the restriction of the handling of hazardous substances to certain parts of the building. Drainage plans and water law notices can provide information on areas in which water-polluting substances were handled during the utilisation phase. Building products with brand names and manufacturers can be found on delivery notes or invoices, which enable further research into pollutants, authorisation and work plans are still available, these can provide initial indications of which parts of the building are likely to contain pollutants. Building permits and notices from the authorities may, for example, mention fire compartments or the restriction of the handling of hazardous substances to certain parts of the building. Drainage plans and water law notices can provide information on areas in which water-polluting substances were handled during the utilisation phase. Building products with brand names

and manufacturers can be found on delivery notes or invoices, enabling further research into pollutants.

Data collection on building history

The building history includes construction, use, conversions and changes of use, renovation and refurbishment measures, operational disruptions, accidents and industrial accidents, natural disasters and fire incidents. The history of a building can provide initial indications of which hazardous substances may have been introduced into the building fabric with the building materials. The history of use and special events during use allow conclusions to be drawn as to what other contamination can be expected. Operational diaries, notifications from authorities, the municipal register of contaminated sites, reports in local newspapers and former employees can be sources of information. However, meaningful documents are often missing.

On-site visit

Knowledgeable people should already be involved in a site visit. The entire building is inspected on the basis of the documents that have been compiled and analysed in advance. Without further investigation, it is already possible to locate areas that show typical discolouration indicating previous fire incidents, the penetration of moisture or operating materials into the building fabric or mould infestation. Areas with biological contamination such as pigeon or rodent droppings and carcasses can also be localised during a site visit. Odours are the most important indicators of critical substances. The inspection must be carried out by people who have undergone odour training for indoor odours and can differentiate between common odours and assign risk factors (smell of PAHs, solvents, old glass wool, animal urine, etc.).

Preparation of an investigation concept, sampling and laboratory tests

Based on the documents and the on-site visit, the sampling points and the necessary scope of testing can now be determined by experts. If necessary, components must be opened and material samples taken. As soon as professional sampling has been carried out and the results of the laboratory tests are available, these must be assessed by qualified persons.

Building diagnosis

Before starting the planning of the conversion, the first step is to carry out the pollutant investigations required for all types of buildings before planning demolition, renovation and repair work (DRR). The verification of building materials and component surfaces containing hazardous substances (**Table B1**) is particularly important for protective measures for employees during DRR work. It also serves to categorise the disposal routes of dismantled materials. Strategies for analysing hazardous substances can be found in DIN EN ISO 16000-32, the VDI 6202 series of guidelines[2,3] and comparable, tried-and-tested analysis concepts[4].

In the case when numerous chemicals were used during the industrial and/or commercial activities on a regular basis, environmental tests should also consider heavy metal compounds, mineral oil and

[2] VDI 6202 Blatt 1: Contaminated structural and technical installations - demolition, renovation and maintenance work. (in German, „*Schadstoffbelastete bauliche und technische Anlagen - Abbruch-, Sanierungs- und Instandhaltungsarbeiten*“)

[3] VDI 6202 Blatt 3: Contaminated structural and technical installations - Asbestos - Investigation and assessment (in German, „*Schadstoffbelastete bauliche und technische Anlagen - Asbest - Erkundung und Bewertung*“)

[4] German Federal/State Working Group on Soil Protection (Bund/Länder-Arbeitsgemeinschaft Bodenschutz - LABO). Geschäftsstelle: Senatsverwaltung für Mobilität, Verkehr, Klimaschutz und Umwelt (SenMVKU), Brückenstraße 6, 10179 Berlin. https://www.labo-deutschland.de/Leistungsbuch-Altlasten-und-Flaechenentwicklung-120--Schadstoffkataster,-Gebaeudeschadstoffe-.html Access: Nov 10, 2023.

chlorinated hydrocarbon contamination and, if necessary, other special chemicals (**Table B2**). These findings serve both occupational safety and, in particular, the protection of future building users from pollutant emissions and undesirable odours.

Material sampling with subsequent laboratory analyses as well as the analysis of air samples and screening procedures should be conducted in accordance with ISO and DIN standards as well as VDI (Association of German Engineers) guidelines. Corresponding information is found in **Appendix C.**

Conclusions

When converting industrial or commercial properties for use as residential buildings, uncertainties may arise regarding possible contamination of the building fabric and site, which can later have undesirable effects on the indoor air quality and thus on the well-being of the users.

It is advisable to consult experts in building diagnostics at an early stage. An expert assessment and a timely investigation reduce both financial and liability risks. If complaints arise only after conversion, subsequent remedial measures might be considerably more costly than when performed during the conversion phase.

Note

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References

[1] Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung – BBSR - im Bundesamt für Bauwesen und Raumordnung - BBR) (eds.): Conversion of non-residential buildings into residential property (in German, „*Umwandlung von Nichtwohngebäuden in Wohnimmobilien*“). BBSR-Online-Publikation 09/2015, Bonn, 62 p. Sep 2015.

[2] Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung – BBSR - im Bundesamt für Bauwesen und Raumordnung - BBR) (eds.): Conversion of non-residential buildings into residential property - documentation of the case studies (in German, „*Umwandlung von Nichtwohngebäuden in Wohnimmobilien – Dokumentation der Fallstudien*“). BBSR-Online-Publikation 10/2015, Bonn, 215 p., Sep 2015.

Appendix A: Abbreviations

Abbreviation	Meaning
BTEX	Benzene, toluene, ethylbenzene and xylenes
KSS	Cooling lubricants
LHKW	Halogenated hydrocarbons
MKW	mineral oil hydrocarbons
PAK	Polycyclic aromatic hydrocarbons
PFAS	Perfluorinated and polyfluorinated alkyl substances
PCB	Polychlorinated biphenyls
PCDD / PCDF	Polychlorinated dibenzo-p-dioxins and dibenzofurans
PCP	Pentachlorophenol
PCT	Polychlorinated terphenyls
TBT	Tributyltin

Appendix B: Pollutants in buildings

Table B1: Typical pollutant groups in buildings

Pollutant	Use as... or origin
Asbestos	Insulation material, electrical insulator, fire protection, brake lining in lifts, thixotropic agent in levelling compounds and tile adhesives, flange seals
Old man-made mineral fibres (KMF)	Insulating material
Lead	Pigment, rust inhibitor, lift weight
Polychlorinated biphenyls (PCB)	Plasticiser, flame retardant, dielectric in capacitors for fluorescent tubes, transformer oil
Pentachlorophenol (PCP), lindane, DDT	Wood preservative
Polycyclic aromatic hydrocarbons (PAH)	Moisture barrier, roofing membranes, tar cork
Chlorofluorocarbons (CFCs)	Refrigerant
TCEP, HBCD	Flame retardant
Phthalic acid esters	Plasticisers
Formaldehyde	Chipboard as a wall and flooring material
Mould fungi	Damp and wet areas
Pigeon and rodent droppings, animal carcasses	--
ammonia	Animal urine in walls and floors, e.g. in horse stables
radon	soil
Deposited dust	--

Table B2: Pollutants typical for industrial sites

Business	Hazardous substances common in the industry
Branch	LHKW, especially trichloroethylene, tetrachloroethylene, PFAS
Dry cleaning Textile industry	LHKW, especially trichloroethylene, tetrachloroethylene, PFAS
Print shop	Chromium(VI) compounds, heavy metals
Electrical industry / plant engineering	PCB, PCT, dioxins (PCDD/PCDF), lead, heavy metals
Precision engineering workshops	LHKW, nitrosamines (KSS), PCB/PCP
Galvanic plants	Heavy metals, LHKW
Gas works/coking plants	PAHS
Foundries	Heavy metals, LHKW
Glass production/processing	Lead, boron compounds
Rubber industry	Nitrosamines, BTEX
Wood impregnation sites	PCP, PCB, lindane, TBT

Business	Hazardous substances common in the industry
Paint shops	BTEX
Agricultural warehouses	Insecticides, pesticides, especially organophosphorus pesticides and organochlorine pesticides
Leather processing/tanneries	Chromium (VI) compounds
Metal processing,	LHKW, MKW, nitrosamines (KSS), PCB/PCP
Ammunition production/shooting range	Lead, arsenic, antimony
Ships/boat workshops	Organotin compounds
Tank farms, petrol stations, vehicle depots	MKW, BTEX

Appendix C: Selected standards, guidelines, recommendations and books

Standards

DIN EN ISO 16000-1	Innenraumluftverunreinigungen - Teil 1: Allgemeine Aspekte der Probenahmestrategie
DIN EN ISO 16000-5	Innenraumluftverunreinigungen - Teil 5: Probenahmestrategie für flüchtige organische Verbindungen
DIN EN ISO 16000-12	Innenraumluftverunreinigungen - Teil 12: Probenahmestrategie für polychlorierte Biphenyle (PCB), polychlorierte Dibenzo-p-dioxine (PCDD), polychlorierte Dibenzofurane (PCDF) und polycyclische aromatische Kohlenwasserstoffe (PAH)
DIN EN ISO 16000-32	Innenraumluftverunreinigungen - Teil 32: Untersuchung von Gebäuden auf Schadstoffe
DIN ISO 16000-3	Innenraumluftverunreinigungen - Teil 3: Messen von Formaldehyd und anderen Carbonylverbindungen in der Innenraumluft und in Prüfkammern - Probenahme mit einer Pumpe
DIN ISO 16000-4	Innenraumluftverunreinigungen - Teil 4: Bestimmung von Formaldehyd - Probenahme mit Passivsammlern
DIN ISO 16000-6	Innenraumluftverunreinigungen - Teil 6: Bestimmung organischer Verbindungen (VVOC, VOC, SVOC) in Innenraum- und Prüfkammerluft durch aktive Probenahme auf Adsorptionsröhrchen, thermischer Desorption und Gaschromatographie mit MS oder MS-FID
DIN ISO 16000-13	Innenraumluftverunreinigungen - Teil 13: Bestimmung der Summe gasförmiger und partikelgebundener dioxin-ähnlicher Biphenyle (PCB) und polychlorierter Dibenzo-p-dioxine/Dibenzofurane (PCDD/PCDF) - Probenahme auf Filtern mit nachgeschalteten Sorbenzien
DIN ISO 16000-14	Innenraumluftverunreinigungen - Teil 14: Bestimmung der Summe gasförmiger und partikelgebundener polychlorierter dioxin-ähnlicher Biphenyle (PCB) und polychlorierter Dibenzo-p-dioxine/Dibenzofurane (PCDD/PCDF) - Extraktion, Reinigung und Analyse mit hochauflösender Gaschromatographie und Massenspektrometrie
DIN ISO 16000-27	Innenraumluftverunreinigungen - Teil 27: Bestimmung von abgelagerten Faserstäuben auf Oberflächen mittels REM (Rasterelektronenmikroskopie) (direkte Methode)

DIN ISO 16000-28	Innenraumluftverunreinigungen - Teil 28: Bestimmung der Geruchsstoffemissionen aus Bauprodukten mit einer Emissionsprüfkammer
DIN ISO 16000-30	Innenraumluftverunreinigungen - Teil 30: Sensorische Prüfung der Innenraumluft
DIN ISO 16000-31	Innenraumluftverunreinigungen - Teil 31: Bestimmung von Flammschutzmitteln und Weichmachern auf der Basis phosphororganischer Verbindungen – Phosphorsäureester
DIN ISO 16000-38	Innenraumluftverunreinigungen - Teil 38: Bestimmung von Aminen in Innenraum- und Prüfkammerluft - Aktive Probenahme von Probenahmeeinrichtungen mit durch Phosphorsäure imprägnierte Filter
DIN ISO 16000-39	Innenraumluftverunreinigungen - Teil 39: Bestimmung von Aminen - Analyse von Aminen durch (Ultra-) Hochleistungsflüssigkeits-chromatographie gekoppelt mit hochauflösender oder Tandem-Massenspektrometrie

VDI (Association of German Engineers) Guidelines

VDI 4300 Blatt 1	Messen von Innenraumluftverunreinigungen - Allgemeine Aspekte der Messstrategie
VDI 4300 Blatt 2	Messen von Innenraumluftverunreinigungen - Meßstrategie für polycyclische aromatische Kohlenwasserstoffe (PAH), polychlorierte Dibenzo-p-dioxine (PCDD), polychlorierte Dibenzofurane (PCDF) und polychlorierte Biphenyle (PCB)
VDI 4300 Blatt 4	Messen von Innenraumluftverunreinigungen - Messstrategie für Pentachlorphenol (PCP) und gamma-Hexachlorcyclohexan (Lindan) in der Innenraumluft
VDI 4301 Blatt 2	Messen von Innenraumluftverunreinigungen - Messen von Pentachlorphenol (PCP) und γ-Hexachlorcyclohexan (γ-HCH) - GC/MS- und GC/ECD-Verfahren
VDI 4301 Blatt 5	Messen von Innenraumluftverunreinigungen - Messen von Flammschutzmitteln und Weichmachern auf Basis phosphororganischer Verbindungen – Phosphorsäureester

VDI 4301 Blatt 6	Messen von Innenraumluftverunreinigungen - Messen von Phthalaten mit GC/MS
VDI 4301 Blatt 7	Messen von Innenraumluftverunreinigungen - Messen von Carbonsäuren
VDI/GVSS 6202 Blatt 1	Schadstoffbelastete bauliche und technische Anlagen - Abbruch-, Sanierungs- und Instandhaltungsarbeiten
VDI/GVSS 6202 Blatt 3	Schadstoffbelastete bauliche und technische Anlagen - Asbest - Erkundung und Bewertung

Other information

AGÖF	https://www.agoef.de/fileadmin/user_upload/dokumente/orientierungswerte/AGOEF-Geruchsleitfaden-2013.pdf
AIR	https://www.umweltbundesamt.de/sites/default/files/medien/4031/dokumente/air_2023_geruchsleitwerte-konzept_bdgsbl_0.pdf
BAUA	Leitlinie für die Asbesterkundung zur Vorbereitung von Arbeiten in und an älteren Gebäuden https://www.baua.de/DE/Angebote/Publikationen/Kooperation/Asbesterkundung.html Access: 21.02.2023
LfU Bayern	Bayerisches Landesamt für Umwelt: Schadstoffratgeber – Gebäuderückbau https://www.lfu.bayern.de/abfall/schadstoffratgeber_gebaeuderueckbau/suchregister/baustoffe/index.htm Access: 21.02.2023

Books

Hans-Dieter Bossemeyer	Gebäudeschadstoffe im Bild. 2020; Verlagsgesellschaft Rudolf Müller,
Hans-Dieter Bossemeyer, Stephan Dolata, Uwe Schubert, Gerd Zwiener	Schadstoffe im Baubestand. 2. aktualisierte und erweiterte Auflage 2019; Verlagsgesellschaft Rudolf Müller
Hans-Dieter Bossemeyer, Gerd Zwiener	Asbest in bauchemischen Produkten. In Lothar Grün (Hrsg.): Gebäudeschadstoffe und Innenraumluft, Band 1; 2021; Verlagsgesellschaft Rudolf Müller
Hans-Dieter Bossemeyer, Gerd Zwiener	Emissionen aus Bauprodukten. In Lothar Grün (Hrsg.): Gebäudeschadstoffe und Innenraumluft, Band 2: 2021; Verlagsgesellschaft Rudolf Müller

Hans-Dieter Bossemeyer, Gerd Zwiener	PCB, Chlorparaffine, Radon, Quarz, Asbest. In Lothar Grün (Hrsg.): Gebäudeschadstoffe und Innenraumluft, Band 3. 2017; Verlagsgesellschaft Rudolf Müller
Hans-Dieter Bossemeyer, Gerd Zwiener	Gerüche in Innenräumen, Arbeiten an schadstoffbelasteten Bauwerken, Sachverständige Probenahme am Dach. In Lothar Grün (Hrsg.): Gebäudeschadstoffe und Innenraumluft, Band 9. 2021; Verlagsgesellschaft Rudolf Müller
Hans-Dieter Bossemeyer, Jutta Witten, Gerd Zwiener	Quecksilber im Innenraum. In Frank Kuebart, Nicole Richardson (Hrsg.): Gebäudeschadstoffe und Innenraumluft, Band 12; 2021; Verlagsgesellschaft Rudolf Müller
Herbert Fromme	Luftverunreinigung in Innenräumen – Vorkommen und gesundheitliche Bewertungen von chemischen, physikalischen und biologischen Faktoren. 2021; Ecomed-Storck
Gesamtverband Schadstoffsanierung e.V.	Schadstoffe in Innenräumen und an Gebäuden. 2. aktualisierte und erweiterte Auflage, 2014, Verlagsgesellschaft Rudolf Müller,
Gunter Hankammer	Schäden an Gebäuden – Erkennen und Beurteilen, Hoch- und Tiefbau. 3. erweiterte Auflage, 2017; Verlagsgesellschaft Rudolf Müller
Siegmund Kaub	Schadstoffe im Bauwesen – Basiswissen für Bau- und Immobilienfachleute. 3. Auflage 2021, Springer
Wolfgang Lorenz, Stefan Betz	Praxis-Handbuch Schimmelpilzschäden – Diagnose und Sanierung. 2. Auflage 2016, Verlagsgesellschaft Rudolf Müller
Peter Pluschke	Luftschadstoffe in Innenräumen. Reprint of the 1st. ed. 1996; 2012; Springer
Peter Pluschke, Hans Schleibinger	Indoor Air Pollution. 2. Auflage 2019, Springer
Adolf Rötzel	Schadstoffe am Bau, 2009, Fraunhofer IRB Verlag