Contract Number P2/00/05

HEMICPD:Horizontal evaluation method for the implementation of the Construction Products Directive:

Emissions to indoor air

State of the art report WP1: Orientation phase

Commissioner

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HEMICPD – Indoor air

HEMICPD: Horizontal evaluation method for the implementation of the Construction Products Directive - Emissions to indoor air
Contract Number P2/00/05

Commissioner
Belgian Science Policy
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Executive summary

In this report an overview of test, analysis and evaluation methods is presented for the assessment of dangerous substances from building products into indoor air. For this purpose the report is outlined as follows:

In the introduction the framework of the HEMICPD project is presented.

The second chapter deals with the different product policy actions concerning indoor environment quality, healthy buildings and construction products at European level and in some European countries.

The third chapter describes the Construction Products Directive and the importance of the implementation of the essential requirement N°3 regarding emissions into indoor air.

In the fourth chapter an overview of dangerous substances possibly emitted from building materials is given.

Chapters 5, 6 and 7 present respectively an overview of the test methods for VOCs & PM, test methods for odour determination and test methods for microbial resistance.

In chapter 8 an elaborate overview of labelling schemes which exist internationally and contain references to indoor air emissions is presented.

In chapter 9 an overview is given of international publications containing emission data on building materials.

Chapter 10 finally describes the building products of concern.

1. Introduction

This state of the art report will serve as guidance document for the selection of test& analysis methods to be used in WP2 and will help to identify the gaps - which will be dealt with in WP3 - in test& analysis methods for the determination of dangerous substances from building materials into indoor air.
Furthermore this report will provide a priority list of building materials from which materials will be chosen in function of the different scenarios and emission tests which will be performed in WP2 and WP3.

The main task of WP1 is to deliver a state of the art report on all relevant information for implementation of the essential requirement N°3 of the Construction Products Directive (CPD) regarding emissions to indoor air. It is important to stress that the general framework of this project is the CPD and the ongoing work in CEN/TC 351 WG2 and EOTA PT9 but some deviations (such as the development of a methodology for microbial resistance, the study of the interaction of ozone with building products and study of the emission behaviour of paints*[1]) from their respective business plans may occur if considered necessary for completion of the objectives and work items put forward in the HEMICPD project description.

For this purpose the report is divided into nine main sections each dealing with a specific topic of relevance in the field of emissions into indoor air:

- Product policy
- Framework
- Dangerous substances
- Test&analysis methods for VOCs and PM
- Methods for odour determination
- Methods for microbial resistance
- Test protocols and labels
- Emission data
- Relevant construction materials

The main goal of the HEMICPD project is the selection & development of adequate test methods for determining the emission of dangerous substances from building materials into indoor air in their intended use scenario.

The state of the art report will not give a description of the (possible) health risks of the different chemicals (possibly) emitted by building materials[1]. Neither will an overview be made of guidance values for the different chemical substances or recommendations for the selection of building materials that have minimal negative effects on the health of the occupants[2,3]. These

[1] * Some categories of paints/coatings (such as intumescent paints (ETAG 018) and concrete repairing coatings) fall under CPD – EOTA route

specific topics are dealt with in a separate ongoing pilot project on construction products and indoor environment and will be investigated further in detail in a new research project[4,5].

The research project HEMICPD is based on the principle of source control for improving indoor air quality. It is demonstrated by different studies that increasing the ventilation rate to speed up the removal of air-borne VOCs, even when energy use is not a concern, is not effective[6,7,8,9]. The most efficient strategy to maintain indoor air quality is to remove the contaminants at the source (source control) and then to rely on ventilation (dilution) to remove the air-borne VOCs.

2. Product policy towards healthy construction products

The perception about the close relationship between indoor environment quality and human health resulted in more and more concern among all stakeholders about healthy buildings and also healthy construction products. Therefore, at different policy levels, as well as by the construction industry itself, various actions concerning indoor environment quality and possible health effects of buildings and building products have already been undertaken.
A brief overview of existing policy documents and studies, as well as some important initiatives concerning indoor environment quality and healthy buildings and construction products at European level, in Belgium (Federal and regional level) and in some European countries (e.g. France, Germany and The Netherlands) is given in the following paragraphs.

A detailed overview and description of all European (and international) initiatives (such as the different indoor materials emissions labelling systems) and research projects - of relevance for the HEMICPD project - is given in sections 3,8, 9 & 10.

2.1. European initiatives

This paragraph gives a brief overview of European policy documents, studies and initiatives on indoor environment quality and building materials and health.

In 2003, the European Commission adopted a new strategy on environment and health with the overall aim to reduce diseases caused by environmental factors in Europe[10]. Among others, air quality is one of the main identified problems of environmental pollution related to health problems such as respiratory diseases, asthma and allergies.
This strategy was followed by the European Environment and Health Action Plan 2004-2010, short the EHAP[11]. This document aims at improving the well-being and maximising the potential economic benefits, at reducing the adverse health impacts of certain environmental factors and at endorsing the cooperation between actors in the environment, health and research fields.
The action plan consists of the following 3 main themes, each with a number of specific actions (13 actions in total) :

- Theme 1 : Improve the information chain by developing integrated environment and health information using (bio)monitoring and environmental health indicators in order to understand the link between sources of pollutants and health effects. This theme includes 4 specific actions;
- Theme 2 : Fill the knowledge gap by strengthening research on environment and health and identifying emerging issues. This theme includes 4 specific actions;
- Theme 3 : Response : review policies and improve communication by developing awarenessraising, risk communication, training and education to give citizens the information they need to make better health choices and to make sure that professionals in each field are alert to environment and health interactions (5 specific actions). Here, *action 12* relates specifically to the improvement of *indoor air quality* through developing networks and guidelines on other factors affecting indoor air quality (e.g. building materials) by using research results and exchange of national best practice.

As a response to this EHAP Action Plan, four initiatives have been undertaken at European level in the framework of indoor air quality, i.e. CEN TC 351, the BUMA project, the Healthy Air project and a new working group on indoor air quality.

The first initiative consists of the *Technical Committee CEN TC 351* "*Construction products : Assessment of release of dangerous substances*", which aims at the development of horizontal standardised assessment methods for harmonised approaches, relating to the release (and/or the content, when this is the only practicable or legally required solution) of regulated dangerous substances under the European Construction Products Directive (CPD), taking into account the intended conditions of use of the product. This action addresses emission from building products to indoor air and release to soil, surface water and ground water. The output of CEN TC 351 will provide the means for the quantification of dangerous substances, as well as for understanding the applicability of such standards in regulations. These standards will provide essential elements in a strategy, leading to the mitigation and possibly the avoidance of the exposure to dangerous substances that may be released from construction products. In addition, potential barriers to trade can be avoided by the use of these standards. The first series of standards, with harmonised release assessment procedures, is expected by 2010-2012. These standards will serve as a basis to fill the essential requirement on ER3 'Hygiene, health and the environment'. The take-up of these European standards in product standards is expected to last about 5 years. After that, the Member States have to define their own thresholds and limit values.

The second initiative, the so-called *BUMA project* (*Prioritisation of Building Material as indoor air pollution sources*), is a new European research project, running from 2005 to 2008, that aims at thoroughly assessing human exposure to air hazards emitted by building materials commonly used throughout Europe, at gaining a better understanding of the sources of hazardous compounds in indoor environment, at forming a comprehensive database with quantified emitted compounds by construction products, at classifying and prioritising building materials, at creating an indoor exposure expert modelling system and at producing relevant guidelines for policy-making actions[12].

The third initiative, the so-called *Healthy AIR project*, is a new European network action for actions and activities that address the effect of construction products on indoor air.

A fourth initiative consists of a new *Expert Working Group on Indoor Air Quality (IAQ) within the Environment and Health Consultative Forum*, which was launched in 2006[13]. The main aims of this working group are to provide a forum for the exchange of information, good practice and knowledge on the relationship between indoor air quality and health, to review, comment and advise on elements of EU programmes relating to IAQ, to provide an interface between relevant projects and activities within countries in relation to IAQ, to evaluate the evidence base of actions and to provide guidance and advise on the implementation of the Action Plan and to examine relevant links to other Community policies to activities carried out by other European and international institutions and organisations.

Other European projects concerning indoor air quality and possible health effects of building products, that form a basis for the European EHAP Action Plan, are the *INDEX* project (Critical appraisal of the setting and implementation of indoor exposure limits in the EU), the *THADE* project (Towards Healthy Air in Dwellings in Europe), the COSI project (Characterization of Indoor Sources) and the EnVIE project[14,15,16,17]. Working Group 3 "Performance in use and new products" of COST action E49 (2005-2009) "processes and performance of wood based panels" is dealing with formaldehyde and VOCemissions from wood based panels[18].

2.2. Belgian initiatives

In Belgium, various documents concerning health and the environment, as well as the possible effects of buildings and construction products on human health, have been worked out. Furthermore, some important initiatives concerning indoor environment quality have been taken. An overview of these documents and initiatives on the different policy levels is given in the following paragraphs.

2.2.1. On the Federal level

In 2003 on initiative of the World Health Organisation (WHO), the Belgian Federal and Regional Governments have worked out the *Belgian National Environment and Health Action Plan* (NEHAP - Belgisch Nationaal Milieu-Gezondheidsplan) which aims at providing a general framework, as well as the necessary means for a common environment and health policy on all policy levels and involving all actors and stakeholders[19].
In this action plan, an extensive overview of all actions and measures concerning the environment and health, as well as indoor air quality, that have already been undertaken at the various policy levels in Belgium (Federal level, Flanders, Walloon Region and Brussels Capital Region), is given.
Furthermore, possible future actions are identified. Such actions include the creation of a common cell for environment and health, as well as a public internet portal, which groups all interesting sites concerning health and environment, and the integration of existing databases on environment and health. Other actions include the harmonisation of scientific research and the uptake of the relationship between health and the environment within basic education programmes (e.g. medicine studies).

Finally, the NEHAP contains seven recommendations and concrete measures concerning the environment and health policy in Belgium. These recommendations concern a functional cooperation between the existing health and environmental institutions, the creation and management of databases, concerning all aspects of health and the environment, the identification of priorities for interdisciplinary research into the relationship between health and the environment and the development of preventive measures based on the results of this research, a preventive policy concerning health and the environment and communication, information, awareness raising and education of the population and professionals on the relationship between health and the environment in order to promote alteration of the existing consumption and production patterns towards sustainable development.

Three other policy documents, which indirectly affect health policy in Belgium, are the *Federal Plan on Sustainable Development 2004-2008,* the *Federal Plan on Product Policy 2003-2005* and the *Federal Product Standards Law*.
- The *Federal Plan on Sustainable Development 2004-2008* represents the Federal strategy for sustainable development in Belgium, of which action 16 aims at developing a strategy for ecologically, economically and socially sound products through their entire life cycle. However, possible health effects of the considered products are neglected in this document[20].
- The *Federal Plan on Product Policy 2003-2005* only partly takes into account building products and their possible health effects. According to this plan, actions have to be undertaken for the following construction materials and products : hard floor coverings, glues, paints and varnishes and packaging[21].
- The *Federal Product Standards Law* and the related implementing orders state that all products, that are brought on the Belgian market, have to bedesigned in such a way that their production, use and removal do not cause any harm to human health and contribute as low as possible to environmental pollution. The main aims of this law are the creation of an integrated, sustainable product policy and the implementation of the European Directives, as well as the integration of dangerous substances into the Belgian policy[22].

Recently a preparatory study for the federal policy related to building products and the environment has been done by BBRI & VITO in which a number of strategic objectives have been defined to achieve “healthy construction products” and which has been used as basis for the section “product policy”[23].

2.2.2. In the Flemish Region

The most important policy document concerning health and the environment in Flanders is the *Environmental Policy Plan*[24]. This document is developed every four years and incorporates the policy and normalisation priorities concerning the environment and health in the Flemish Region. The plan, inter alia, aims at reducing and stopping emissions or use of dangerous substances during the production or within products and therefore wants to interfere on the following health aspects :
- Indoor air quality with as main aspects the prevention for CO poisoning, moisture, fungus and allergic reactions, formaldehyde, smoke and NO_x emissions;
- Product policy with as possible measures a ban on dangerous substances or replacement of hazardous substances with less dangerous alternatives;

- Reduction of the emissions of household VOCs through reduction of the use of household products emitting VOCs (e.g. paints, thinners, varnishes, glues and stains);
- Reduction of NO_x emissions in households;
- Reduction of the emissions of environment-unfriendly substances (e.g. through agreements between the government and the industry);
- Reduction of the emissions of PAHs through product normalisation and policy on the use of the products emitting PAHs;
- Information on the risks of asbestos through information campaigns to target groups concerning removal and treatment of asbestos in buildings and strengthening of the policy and control on risk situations concerning asbestos.

Specific regulations on the indoor environment in Flanders are given in the *Flemish Indoor Environment Decree of 2004*[25]. This decree states that everyone that is responsible for the construction, management and equipment of public buildings is obliged to reduce as far as possible all health risks of the indoor environment on inhabitants and users. Therefore, this decree regulates research and measures on the indoor environment in dwellings and public buildings, as well as all competences of the Flemish Health Inspection (Vlaamse Gezondheidsinspectie) and of all medical-environmental experts. Furthermore, within this decree, quality standards on the indoor environment in Flanders are set.

Within the OVAM *Sectoral Plan on Environmentally-sound Use of Materials and Waste Management in the Construction Sector*, only two sentences are devoted to the health aspects of building materials[26]. These sentences indicate that the most dangerous materials during renovation and demolition of buildings are asbestos, PCB's and tar-containing substances and materials and that the effects of asbestos-replacing fibres on human health are not or only partly known yet.

Within the *Flemish Housing Code* (Vlaamse Wooncode), which can be interpreted as the Flemish basic law on living, quality standards for housing, essential safety, health and living quality requirements, control mechanisms and also some criteria concerning indoor air quality (e.g. light, ventilation, moisture, CO risks) are regulated[27,28].

One important study, supporting the Flemish indoor environment policy, is the report on the *Elaboration of a Flemish policy on the indoor environment*[29]. In this study, the existing Belgian and European legislation on building products is mentioned (e.g. Federal Product Standards Law, the Flemish Housing Code and the European Construction Products Directive) and an overview of the ten most relevant disturbances on the indoor environment in dwellings is given. Furthermore, based on the available information, a priority list, as well as recommendations and actions concerning the future indoor environment policy in Flanders are identified.

The identified most relevant disturbances on the indoor environment in dwellings are the following :
- chemical substances, such as volatile organic compounds (VOCs) due to emissions from *building materials* (e.g. floor coverings, chipboard, insulation materials, …), furniture and other household products (e.g. paints and varnishes, glues, …);
- combustion products;

- non-biological substances, such as dust, asbestos and other mineral fibres (e.g. insulation materials), lead (e.g. paints and solder materials) and mercury;
- radon radiation (e.g. plasterboard);
- non-ionising radiation;
- ions;
- biological substances, such as dust mites, pets and fungi;
- noise;
- odour (e.g. paints, floor coverings and furniture);
- physical parameters, such as temperature and draught.

Following problems and needs concerning the indoor environment quality in Flanders have been identified in this study (and the subsequent actions):
- there is a lack of data concerning representative levels for hazardous substances in dwellings and a lack of limit values for hazardous substances in the indoor environment;
- there is a need for scientific support of the policy, because of lack of knowledge on emissions, exposure and related health effects on the population in Flanders;
- there is a need for information gathering on indoor environment quality in central databases and for information dissemination towards the public;
- there is a need for an integrated approach on indoor environment quality and for coordination of existing initiatives on indoor environment in Flanders;
- the policy on products, waste management and emissions of substances has to be further developed;
- the weakest groups of the population have to be protected against adverse health effects of buildings and building products.

Apart from policy documents, also various *information brochures* towards the public have been developed by the Flemish government. Three examples of such information documents are described here.
- 'Living and health' (Wonen en Gezondheid) gives first an overview of all factors, that influence the indoor environment in dwellings and an overview of the relevant legislation as well as some recommendations for a healthy dwelling[27].
- 'Construction and health. Information for builders and renovators that want a healthy house' (Bouwen en Gezondheid, Informatie voor bouwers en verbouwers, die een gezonde woning willen) is a brochure that provides clearly understandable information on how builders and renovators can obtain a healthy dwelling[30].
- 'Healthy building or renovation. Healthy living ?' (Bouw of verbouw gezond. Gezond wonen?) is a brochure that provides information on the different causes of indoor air pollution and their health effects, as well as recommendations to the public[31].

An important initiative concerning indoor environment quality in Flanders consists of the so-called LOGO's (Lokaal Gezondheidsoverleg in Vlaanderen - Local Health Consultation Flanders), which consist of a network of local partners from health and related sectors, that work together to locally implement health projects and to develop an integrated health policy in companies, schools, municipalities and other settings[32,33].

2.2.3. In the Walloon Region

Research in the Walloon Region concerning the environment and health resulted in a cooperation between two Walloon organisations (Inter-Environnement Wallonie and Société Scientifique de Médecine Générale) that lead to the development of the European sensibilisation project *Sandrine 1* (Santé développement durable information environnement - Health, sustainable development,information, environment)[34]. This project (running from 1998 to 2001) aimed at informing medical specialists, architects and the public about the risks of indoor environment pollution. Later on, the *Sandrine 2 and 3 projects* resulted in the development of the so-called *Green Ambulances* service (Ambulances Vertes) and in the publication of the information brochures with the titles 'My house in good health, small guidelines for indoor contaminants' (Ma maison en bonne santé, petit guides des polluants intérieurs) and 'Green ambulances, a service for detection of indoor contaminants' (L'ambulance verte, un service de detection des polluents intérieurs).
The document with the title '*Health and housing conditions - the issue of indoor pollution*' (La Santéet l'Habitat - Problématique des pollutions intérieures) was distributed as an information document during a press conference in the Walloon Region as a first step within a sensibilisation and informationcampaign '*Health within Houses*' (Santé dans l'Habitat), which handles about the effects of indoor living conditions on human health[35]. This sensibilisation and information campaign was managed by the Walloon association Espace Environnement and finds its origin in the European project Sandrine (Santé développement durable information environnement). The main objectives of this Health within Houses project are to reduce health risks related to indoor pollution, to guarantee the use of the results of the Sandrine project and to assure the continuation and enforcement of information and sensibilisation actions concerning the indoor environment towards the public. To achieve the latter goal, various informationsheets on the different contaminants (e.g. moisture, pesticides, …) have been published and a permanent telephone service was offered. Also special courses and study days for construction specialists have been organised.

2.2.4. in the Brussels Capital Region

A policy document of the Brussels Government concerning building materials and the environment bears the title '*Towards a construction and environment strategy for sustainable development in the Brussels Capital Region*' (Vers une stratégie construction et environnement pour le développement durable en Région de Bruxelles-Capitale)[36]. This draft document gives an overview of the state of the art of indoor air quality in Brussels and describes some recent actions on indoor air pollution prevention and reduction in the Brussels-Capital Region. However, specific actions on the health aspects of building materials are not included in this document.

One example of specific actions undertaken in the framework of the above mentioned action plan consists of the creation in 2000 of the *Regional Intervention Cell for Indoor Pollution* (CRIPI - Cellule Régionale d'Intervention en Pollution Intérieure - RCIB - Regionale Cel voor Interventie bij binnenluchtvervuiling)[37]. This Cell aims to study and evaluate indoor pollutions in Brussels and to intervene in case of indoor pollution in dwellings using the so-called *Green Ambulances* (Ambulances Vertes or Groene Ambulances). These Ambulances consist of a team of specialists, that analyse the indoor environment within the dwelling and provide advice and remediation measures to remove indoor pollution. Based on the in this way collected data, the Brussels Government wants to develop a long-term strategy and actions (recommendations, treatments, guidelines, …) concerning the indoor environment issues.

2.3. Foreign initiatives

This paragraph gives a brief overview of some foreign policy documents, studies and initiatives on indoor environment quality and building materials and health.

Within the study '*Product Policy in the Context of the Indoor Environment Quality*' of 2006, recent product and indoor environment policies concerning 14 priority contaminants (i.e. formaldehyde, 1,2,4-trimethylbenzene, alpha-pinene, toluene, triclosan, methylene-di-isocyanate, glycol ethers, permethrin, D-limonene, benzene, acetaldehyde, vinyl chloride, trichloroethylene and brominated flame retardants) in 8 different countries (i.e. Sweden, Finland, France, Germany, California (U.S.A.), Canada, Denmark, Poland) have been reviewed and conclusions on the existing indoor environment policy have been drawn[38].
An overview of the most important information and the main conclusions from this study is given in the following paragraphs.
An important observation concerning the selected pollutants is that for most substances direct national product policy or initiatives in function of the indoor air quality and the limitation of the usage of certain toxic substances in products are missing in the selected countries and that most national legislation is based on European directives, such as the Directive of Dangerous Substances. This lack of national legislation is mainly due to a lack of information on the real toxicity of many of the considered substances. The substances, which are regulated through European directives, are formaldehyde, benzene, some glycol ethers, brominated flame retardants, chlorinated solvents and vinyl chloride. Additionally, only few substances are regulated concerning indoor air quality at national level in some countries (e.g. CO_2, ammonia, asbestos, formaldehyde, CO, PM_{10}, radon and some VOCs and sometimes also physical characteristics and biological particles).
Although direct regulation of chemical substances in products is almost always missing, the indoor air quality in the selected countries is also influenced by other policy measures and actions.
It seems that the most successful initiatives out of the above mentioned measures are in fact voluntary agreements, such as a labelling system, and different publications, such as guides, reports, articles and books at the popular science level. Finally, a series of recommendations concerning policy on building products and indoor air quality is given in this study.

A detailed overview and comparison of the different labelling systems in different countries is given in section 8.

In California indoor air quality (IAQ) issues related to the selection and handling of building materials are described in the so called California 01350 specification[39]. The influence of building materials on IAQ is screened based on:

- Emissions testing protocol
- Hazardous content screening and
- Avoiding mold and mildew from construction practices

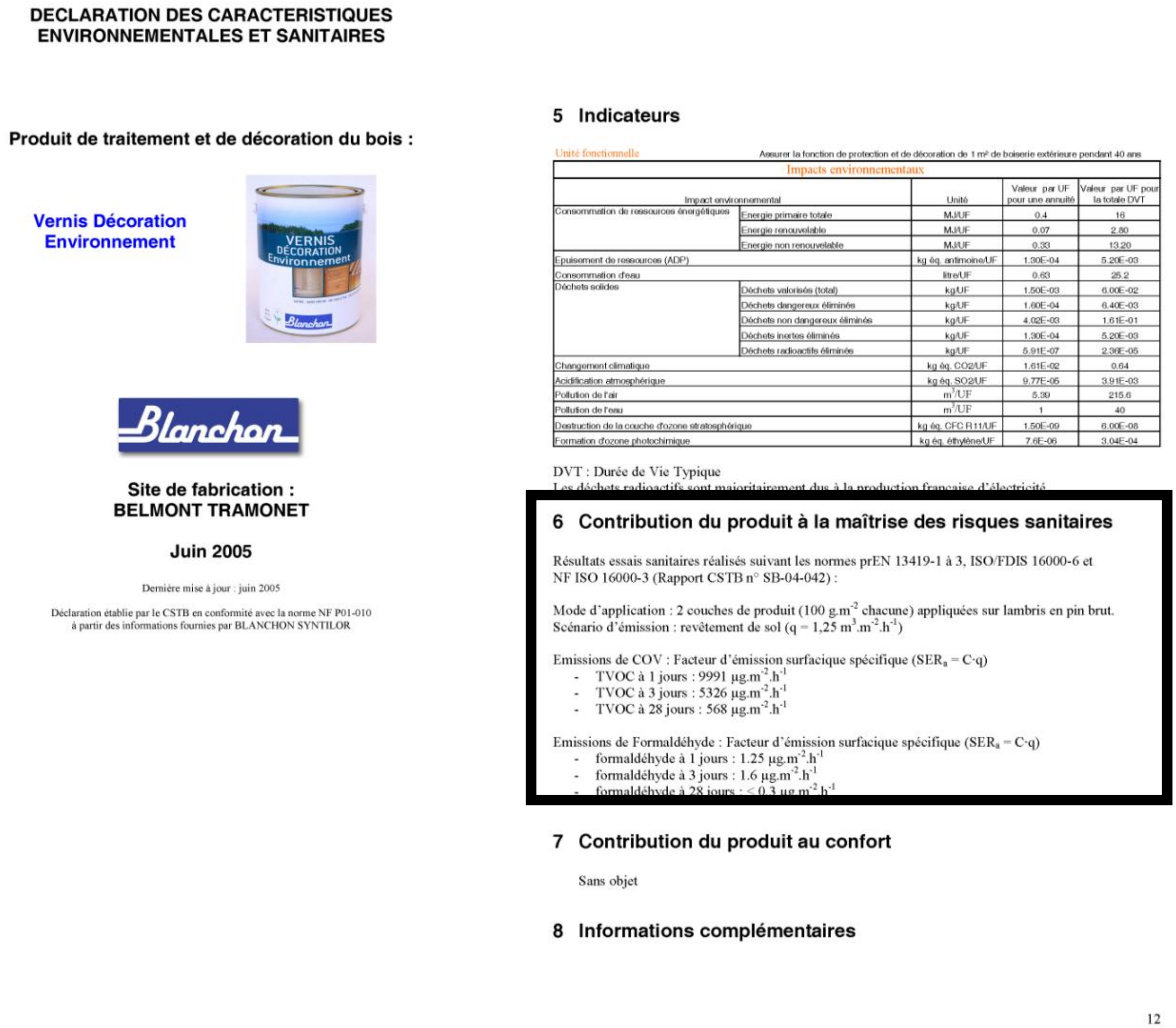
Recently, a new WHO working group has been created to deal with exposures to biological agents in indoor environments[40].

A very important document concerning the indoor environment and health in buildings in France is the *French National Environment and Health Plan* (PNSE - Plan National Santé Environnement) of 2004[41]. This plan consists of a list of 45 actions concerning health and the environment that must be implemented by 2010 in order to arrive at a more sustainable society in France. Several of these actions directly relate to the indoor environment quality, as well as to *building products*, and their related health effects. Examples of these actions are the following :
- Action 15 : labelling of the environmental and health characteristics of building products, including the development of a database and voluntary labelling, as well as recommendations to the authorities to only purchase labelled products and development of concrete measures to reduce VOC and formaldehyde emissions from building products;
- Action 17 : reduce the exposure of inhabitants to radon radiation through new building legislation in sensitive areas and through information sessions and promotion campaigns for consumers and professionals;
- Action 18 : reduce the exposure of inhabitants to artificial mineral fibres through limitation of the usage of these fibres in building materials and products and through information towards consumers and professionals;
- Actions 20, 21, 22 and 23 : reduce the exposure of inhabitants to chemical substances, such as carcinogenic, mutagene, reprotoxic and persistent, toxic compounds, through the development of maximum exposure values.

Another initiative in France is the so called HQE ("Haute Qualité Environnemental") which contains 14 requirements ("cibles") organized in two domains: the minimisation of impacts on the outdoor environment and to produce a satisfying indoor environment[42]. For indoor air following three requirements are important:

1. "Cible N°11: Confort olfactif; choix de produits faiblements émetteurs d'odeurs"
2. "Cible N°12: Qualité sanitaire des espaces; choix de produits favorisants de bonnes conditions d'hygiène"
3. "Cible N°13: Qualité sanitaire de l'air; choix de produits faiblement émetteurs de polluants de l'air"

Furthermore it is important to note that information about indoor air is also included in the (French) INIES database which compiles environmental characteristics of building materials[43]. An example is shown in Figure 1.



DECLARATION DES CARACTERISTIQUES ENVIRONNEMENTALES ET SANITAIRES

Produit de traitement et de décoration du bois :

Vernis Décoration Environnement

Blanchon

Site de fabrication :
BELMONT TRAMONET

Juin 2005

Dernière mise à jour : juin 2005

Déclaration établie par le CSTB en conformité avec la norme NF P01-010 à partir des informations fournies par BLANCHON SYNTILOR

5 Indicateurs

Unité fonctionnelle — Assurer la fonction de protection et de décoration de 1 m² de boiserie extérieure pendant 40 ans

Impacts environnementaux				
Impact environnemental		Unité	Valeur par UF pour une annuité	Valeur par UF pour la totale DVT
Consommation de ressources énergétiques	Energie primaire totale	MJ/UF	0.4	16
	Energie renouvelable	MJ/UF	0.07	2.80
	Energie non renouvelable	MJ/UF	0.33	13.20
Epuisement de ressources (ADP)		kg éq. antimoine/UF	1.30E-04	5.20E-03
Consommation d'eau		litre/UF	0.63	25.2
Déchets solides	Déchets valorisés (total)	kg/UF	1.50E-03	6.00E-02
	Déchets dangereux éliminés	kg/UF	1.60E-04	6.40E-03
	Déchets non dangereux éliminés	kg/UF	4.02E-03	1.61E-01
	Déchets inertes éliminés	kg/UF	1.30E-04	5.20E-03
	Déchets radioactifs éliminés	kg/UF	5.91E-07	2.36E-05
Changement climatique		kg éq. CO2/UF	1.61E-02	0.64
Acidification atmosphérique		kg éq. SO2/UF	9.77E-05	3.91E-03
Pollution de l'air		m^3/UF	5.39	215.6
Pollution de l'eau		m^3/UF	1	40
Destruction de la couche d'ozone stratosphérique		kg éq. CFC R11/UF	1.50E-09	6.00E-08
Formation d'ozone photochimique		kg éq. éthylène/UF	7.6E-06	3.04E-04

DVT : Durée de Vie Typique
Les déchets radioactifs sont majoritairement dus à la production française d'électricité

6 Contribution du produit à la maîtrise des risques sanitaires

Résultats essais sanitaires réalisés suivant les normes prEN 13419-1 à 3, ISO/FDIS 16000-6 et NF ISO 16000-3 (Rapport CSTB n° SB-04-042) :

Mode d'application : 2 couches de produit (100 $g.m^{-2}$ chacune) appliquées sur lambris en pin brut.
Scénario d'émission : revêtement de sol ($q = 1,25\ m^3.m^{-2}.h^{-1}$)

Emissions de COV : Facteur d'émission surfacique spécifique ($SER_a = C \cdot q$)
- TVOC à 1 jours : 9991 $\mu g.m^{-2}.h^{-1}$
- TVOC à 3 jours : 5326 $\mu g.m^{-2}.h^{-1}$
- TVOC à 28 jours : 568 $\mu g.m^{-2}.h^{-1}$

Emissions de Formaldéhyde : Facteur d'émission surfacique spécifique ($SER_a = C \cdot q$)
- formaldéhyde à 1 jours : 1.25 $\mu g.m^{-2}.h^{-1}$
- formaldéhyde à 3 jours : 1.6 $\mu g.m^{-2}.h^{-1}$
- formaldéhyde à 28 jours : < 0.3 $\mu g.m^{-2}.h^{-1}$

7 Contribution du produit au confort

Sans objet

8 Informations complémentaires

12

Figure 1: Example from INIES database: "fiche de déclaration environnementale et sanitaire"

In the German Federal State of North-Rhine-Westphalia, the main document concerning the environment and health consists of the *Environment and Health Action Programme* (APUG NRW - Aktionsprogramm Umwelt und Gesundheit Nordrhein-Westfalen), which is a regional implementation of the Federal Environment and Health Action Programme (APUG - Aktionsprogramm Umwelt und Gesundheit)[44].

A specific part of this programme concerns healthy living (housing and health) and the possible impacts of *building materials* on human health and aims at improving the information for building experts and consumers with respect to identifying indoor air pollution sources, with respect to healthy modernisation and renovation of old buildings and about the labelling of building products. Two types of guidelines have been prepared within this framework :

- Healthy modernisation : The guideline consists of photos of typical examples of contaminated construction elements in old buildings, which makes it easier for building experts to identify potentially health-hazardous building materials. Polluted construction elements can be specifically analysed and replaced within the framework of refurbishment or modernization projects;
- Product labelling of building materials : People wishing to use environmentally and health compatible building materials usually refer to the product designation or label. The guideline provides an in-depth description of common labels in Germany, concerning health and the environment, fitness for use and social compatibility and makes it easier to understand existing labels and provides support to consumers with respect to the choice of environmentally and health-compatible building materials.

In Sweden the building sector has identified the following significant environmental aspects of their sector: the use of energy, the use of materials, the use of hazardous substances and the impact on indoor air quality in buildings. To reduce the environmental impact the "environmental program 2003-2010" has been conducted[45]. Objective 4 "Secure sound indoor environment" is the relevant topic concerning indoor air quality and is formulated as follows:

- New buildings should be designed, built and maintained in a way that secures a sound indoor environment
- Existing buildings that causes health problems should be identified and remedies should be carried out latest by 2010.

Objective 3 of the environmental program is the phasing out of very dangerous substances from the construction sector. The BASTA system is aimed at phasing out substances with particularly hazardous properties from construction products. Those construction products that meet the following maximum admissible concentration limits for specified property, and where the supplier meets the terms of contract may be registered in the BASTA database[46]. The properties criteria are based on the properties identified in the REACH regulation, plus the phase-out substances identified by the Swedish Parliament, lead, cadmium and mercury.

The so called "Ecocycle Council" is an association of around 30 organizations within the Swedish building and real estate sector which aims to reduce the environmental impact of the building sector[47].

Finally, in The Netherlands, the main document concerning health and the environment is the *Action Programme Environmental Health 2002-2006* (Actieprogramma Gezondheid en Milieu 2002-2006) of 2002[48].
The main aims of this programme consist of the improvement of the environment and the reduction of health problems due to environmental aspects, the maintenance of safety, comfort and welfare in buildings and the prevention of risks to the health of the users. The four themes identified within this programme are a healthy local environment, risk communication to citizens, a healthy indoor environment in buildings and dwellings and general environmental and health policy, while the related strategic lines consist of integrated and transparent decisions, information and communication and innovation.

3. Framework of the European Construction Products Directive

The Construction Products Directive (CPD) 89/106/EEC of 21 December 1988 has the purpose to eliminate technical barriers to trade for construction products[49]. This goal is being achieved by requesting Member States to take all necessary measures that only products, which are fit for the intended use, may be put on the market. One the other hand products which are considered fit for their intended use in one Member State, must be allowed to be used in the other Member States. The main scope of the directive is abolishing unjustified technical barriers in the free movement of Construction Products. At this moment the CPD is under revision to make this legislative tool more simple and transparent, improve its effectiveness, and reduce the costs of its implementation[50,51].

Fit for the intended use means, that the product has such characteristics that the works in which they are to be incorporated, assembled, applied or installed, can, if properly designed and built, satisfy the essential requirements, referred to in Article 3 of the CPD, when and where such works are subject to regulations containing such requirements[52].

For the purpose of the CPD “construction product” means any product, which is produced, for incorporation in a permanent manner in construction works including both buildings and civil engineering. Construction products also include installations and parts and therefore heating, air, ventilation, sanitary purposes, electrical supply and storage of substances harmful to the environment, as well as prefabricated construction works which are marketed as such (for example prefabricated houses).

A construction product is relevant for emission into indoor air under CPD if it can release dangerous substances during its intended conditions of use phase when the consumer is present.

Further to this the Commission has issued a Guidance Paper C, covering the treatments of kits and systems under the CPD[53]. A construction product is a “kit”, when it is a set of at least two separate components that need to be put together to be installed permanently in the works. There it becomes an “assembled system”. A kit is a construction product, an assembled system is not.

For construction products which conform to a harmonised European specification according to the CPD and which bear the CE-marking it shall be presumed, that they are fit for the intended use.
Construction products to be accepted within the EU market need, according to the CPD, to fulfill the essential requirements (ER) in order to receive the CE-label. While in other product directives the essential requirements are directed to the products themselves, the CPD relates the essential requirements to the works. The safety of workers erecting the works are not covered by the CPD, other directives or national regulations apply for this. To conform to the scope of the CPD, the harmonised approach is limited to “works in use”. To achieve works that fulfill the essential requirements in use, the products must be fit for the intended use. The essential requirements for works are given in annex I of the CPD. These are:

1. Mechanical resistance and stability
2. Safety in case of fire
3. **Hygiene, health and the environment**
4. Safety in use
5. Protection against noise
6. Energy economy and heat retention

All these requirements must, subject to normal maintenance of the work, be satisfied for an economically reasonably working life, i.e. durability of the performance characteristics is a precondition. The essential requirement N°3 (ER3) is intended to contribute to protecting the health of occupants and neighbours as well as the immediate environment. In annex I of the CPD it is stated that the construction works must be designed and built in such a way that it will not be a threat to the hygiene and health of the occupants or neighbours, in particular as a result of the following:

- The giving-off of toxic gas
- The presence of dangerous particles or gases in the air
- The emission of dangerous radiation
- Pollution or poisoning of water or soil
- Faulty elimination of waste water, smoke and solid or liquid wastes
- The presence of damp in parts of the works or on surfaces within the works

From these essential requirements for the works the necessary characteristics for products to be fit for the intended use are derived. This link between essential requirements and the technical specifications for products is established through the "Interpretative Documents".
The Interpretative Documents shall:

- Give concrete forms to the essential requirements and detail them, e.g. by indicating classes and levels;
- Indicate the correlation between requirements to works and the product characteristics;
- Lay down the product characteristics and their classes if any that shall be taken into account in the product specifications.

ER3 is given a concrete form in the *Interpretative Document N°3*. It stipulates that the harmonised technical specifications for construction products must cover the following characteristics for the period of use of the construction works:

- Release of pollutants *to indoor air* (e.g. VOC, inorganic and organic particles and radioactive substances)
- Release of pollutants to outdoor air, soil and water in the immediate environment of the works

Guidance Paper H gives further advice as to the necessary procedural rules[54]. Although it is not legally binding, the Guidance paper has a high status. The guidance Paper H is intended to describe a harmonized approach on addressing the problem of dangerous substances, when related to products falling under the CPD. It explains the extent to which the Directive applies to dangerous substances and how technical specification writers (CEN/CENELEC and EOTA members) should take them into account to achieve harmonisation. Technical specifications were intended to provide all the relevant details for a given construction product and in particular the necessary information required for a producer to be able to complete the CE Marking.

Aspects of health, hygiene and environment that are related to the manufacturing of products or their function (e.g. faulty disposal of wastewater) are not considered. The Guidance Paper H (& ER3) does not cover construction products in contact with water intended for human consumption as they are covered by the European Acceptance Scheme (EAS), which is under development.

ER3 is not only part of the CPD as an instrument of a New Approach Directive to create the single market, it is also embedded in Community policies and legislation concerning environmental and health and safety issues as discussed in section 2.

According to the CPD, European *Technical Specifications* are European Product Standards, adopted by *CEN* under a mandate of the Commission (harmonised standards) and European Technical Approvals issued by a member body of *EOTA*. An overview (snapshot) of the drafts/standards linked with the CPD and cited in the Official Journal (mandated, the so called "harmonized standards") is given in Figure 2[55].

Concerned standards	**477**
Approved ENs	
Approved Standards cited in the Official Journal	376
Approved Standards not yet cited in the Official Journal	34
Approved Standards not yet available	4
Total approved Standards	**414**
Drafts which have completed FV or UAP	
Approved Drafts not yet ratified	0
Failed Formal Vote or Unique Acceptance Procedure Drafts	6
Drafts which are under FV or UAP	
Drafts undergoing Formal Vote or Unique Acceptance Procedure	2
Drafts received in CEN Management Center for Formal Vote preparation	6
Drafts received in CEN Management Center for UAP preparation	1
Drafts before FV or UAP	
Drafts passed CEN Enquiry	22
Drafts undergoing CEN Enquiry	4
Drafts received in CEN Management Center for Enquiry preparation	6
Drafts not yet received in CEN Management Center for Enquiry preparation	16
Drafts in development deleted from the CEN database as the 3-years timeframe was exceeded by the CEN/TCs in charge	23

Figure 2: Snapshot of the current situation for standards to be cited in the OJ under the CPD (date: March 2010)

To inform users of the European product standards which clauses are part of the harmonised standard (and basis for the CE-marking), each harmonised standard contains an “annex ZA”. This informative, yet mandatory - for manufacturers aiming at putting products on the market in the EEA – annex indicates the clauses which form the harmonised part of the standard. The annex ZA also informs manufacturers about the applicable systems(s) of conformity assessment (vide infra,

Table 1: Systems of attestation of conformity (under the CPD). M= manufacturer / NB= notified body

Member states shall presume that construction products are fit for the intended use, if the products comply with the requirements of the relevant harmonised European standards or a European Technical Approval. The main and usual route is the harmonized standard. European technical approvals (ETAs) may be granted to:

- Products for which there is neither a harmonized standard, nor a recognized national standard, nor a mandate for a harmonized standard, and for which the Commission, after consulting the SCC, considers that a standard could not, or not yet, be elaborated; and
- Products which differ significantly from harmonized or recognized national standards

The European Commission has recently upgraded environmental and health aspects on its agenda for a common market for construction products. In April 2005 a *mandate M/366* was issued to CEN to develop harmonised approaches for dangerous substances under the CPD[56]. CEN has established a new Technical Committee (*CEN/TC 351*) as a response to the EC mandate. The new TC had its first meeting on 19th to 21st April 2006. The structure of CEN/TC 351 is depicted in Figure 4. The scope of this TC is defined as follows: “Development of horizontal standardised assessment methods for harmonised approaches relating to the release (and/or the content when this is the only practicable or legally required solution) of regulated dangerous substances under the Construction Products Directive (CPD) taking into account the intended conditions of use of the product. It addresses emission to indoor air, and release to soil, surface water and groundwater.” *Working Group 2 (WG2) of CEN/TC 351* deals with the emissions from construction products into indoor air. A schematic overview of the different topics of investigation in this WG is shown in Figure 3[57].

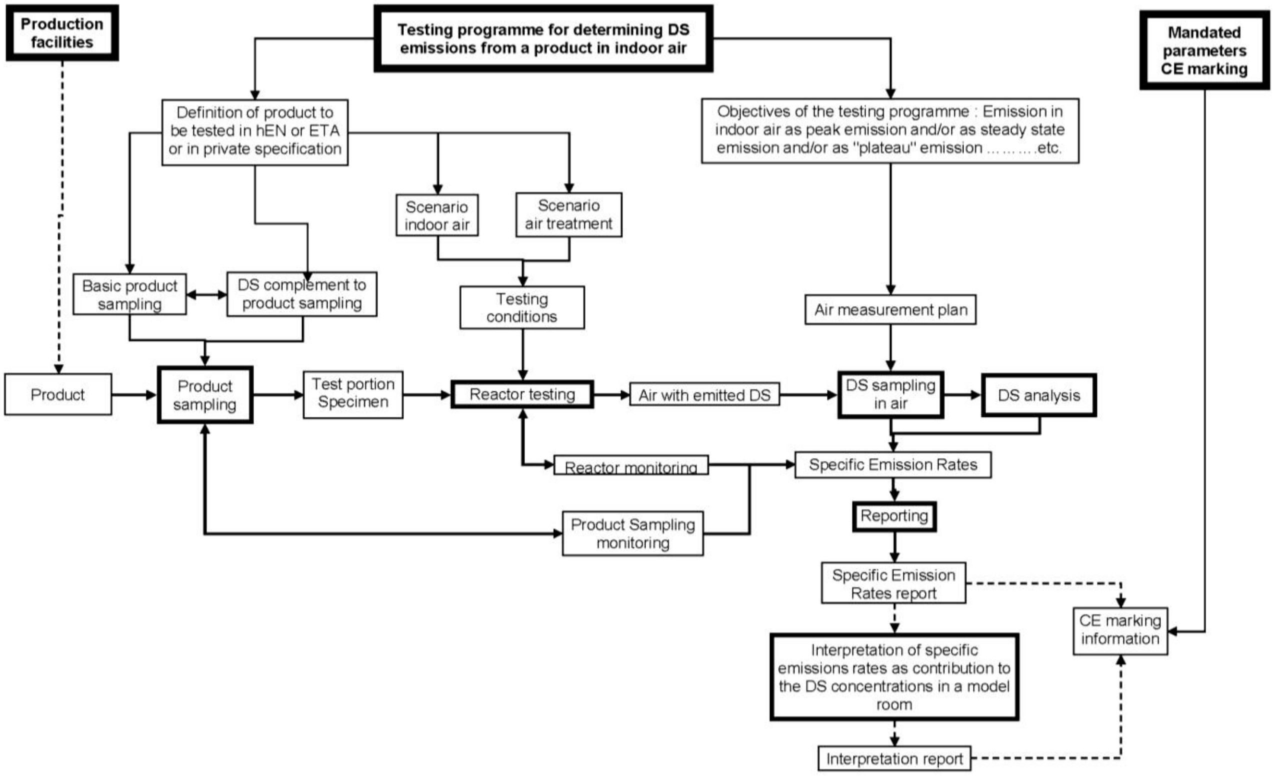


Figure 3: Overview of topics under investigation in CEN/TC 351 WG2 (indoor air)[57]

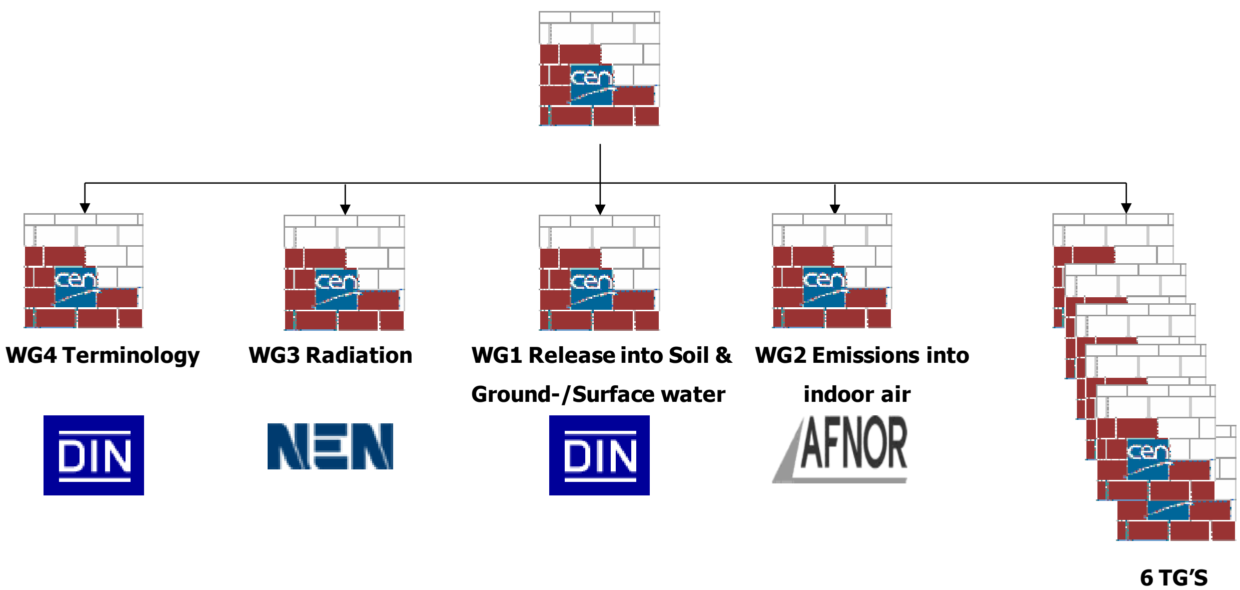


Figure 4: Current (January 2010) structure of CEN/TC 351

Six Task Groups have been established in CEN/TC 351 which are responsible for drafting 6 technical reports (and 1 state of the art report) which will serve as guidance documents for the work of CEN/TC 351 and its working groups (WG1 & WG2):

- TG1 is responsible for TR1: "barriers tot trade"[58]

- TG2 is responsible for TR2 & TR4: “horizontal test methods” & “use of horizontal methods”[59,60]
- TG3 is responsible for TR3: “WT/WFT”[61]
- TG4 is responsible for TR5: “Complement to sampling”[62]
- TG5 is responsible for TR6: “Content”[63]
- Work of TG6 is transferred to WG3 “Radiation from construction products”[64]
- TG7 is responsible for TR on the issues associated with the statistical aspects of data and technical classes[65]

Following work items of the CEN/TC 351 Business Plan belong to the tasks of WG2[66]:

- WI 9: Methods for generation of emission of dangerous substances from construction products into indoor air in standardized testing facilities
- WI 10: The measurement of regulated dangerous substances in indoor air samples as generated from construction products in standardized testing facilities

WI 9 and WI 10 are combined in new WI “Determination of emissions into indoor air”(resolution 63 of October 2007 CEN/TC 351 meeting)

- WI 11: The measurement of radiation and radioactive emissions from construction products
- WI 12: The assessment for potential growth of relevant micro-organisms on construction products in the indoor environment

WI 12 is on hold: prenormative research is needed. The same applies for testing sensory emissions of construction products.

At EOTA level PT9 (*EOTA PT9*) has been created to deal with ER3 in technical approvals (Figure 5)[67,68].

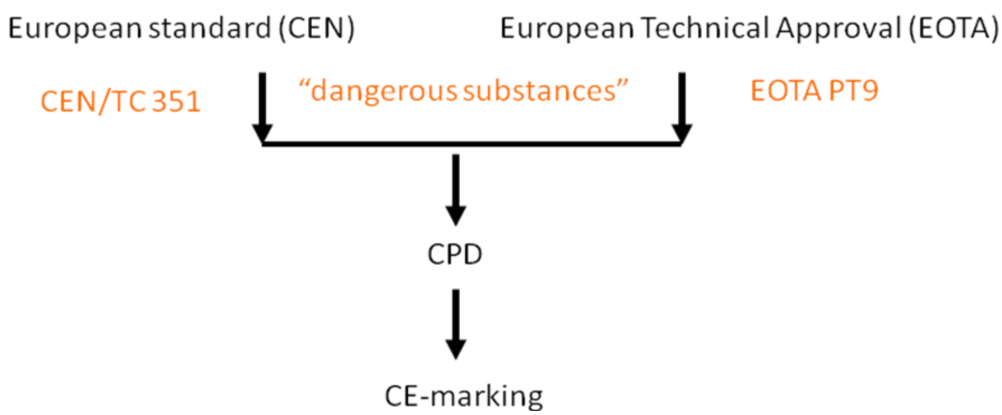


Figure 5: European Technical Specifications and corresponding TC (technical committee) or PT (project team) in the domain of dangerous substances

Before placing a product on the EU market, the manufacturer must subject his product to conformity assessment procedures provided for in the applicable directive, before affixing the CE Marking. Third party conformity assessment is carried out by notified bodies, which have been designated by the member States amongst bodies that fulfill the requirements, laid down in the directive and that are established on their territory.

The following six systems of attestation of conformity are used under the CPD (annex III)[69]. The systems are classified to the degree of involvement of third parties in assessing the conformity of the product:

- System 1+: Product conformity certification with audit testing
- System 1: Product conformity certification without audit testing
- System 2+: Factory production control (FPC) certification with continous surveillance
- System 2: Factory production control (FPC) certification without surveillance
- System 3: Initial type testing (ITT) by notified bodies
- System 4: No involvement of notified bodies

The tasks for the manufacturer and for the notified body are shown in Table 1. Note that for all systems, including the least onerous system (system 4), the manufacturer is required to have a fully recorded system of factory production control (FPC). The attestation procedures for a product are set out in detail in the relevant technical specification. For standards these appear usually in annex ZA.2 and for ETAGs in chapter 8.

	System of attestation of conformity					
Elements of the control of conformity	**1+**	**1**	**2+**	**2**	**3**	**4**
Factory production control (FPC)	M	M	M	M	M	M
Testing of samples taken at the factory by the manufacturer in accordance with a prescribed test plan	M	M	M	M		
Initial type testing (ITT)	NB	NB	M	M	NB	M
Initial inspection of the factory and FPC	NB	NB	NB	NB		
Continuous surveillnace, assessment and approval of the FPC	NB	NB	NB			
Audit-testing of samples taken at the factory, on the market or on the construction site	NB					

Table 1: Systems of attestation of conformity (under the CPD). M= manufacturer / NB= notified body

A detailed description of ITT and FPC is given in Guidance Paper M[70]. An outline of the manufacturers declaration of conformity and for the certificate of product conformity (if relevant) is given in guidance paper D, and will normally be included in annex ZA.3 of the product standard or chapter 8 of the ETAG respectively[71].

For ITT and routine testing there will be a need for simplified measurement/test methods for determining the emissions of dangerous substances into indoor air[72].

A detailed description of the Belgian[73] and other national systems of acceptance and approval of construction products and related marks in Europe can be found in the PRC report[74].

The distinction between the declared value accompanying the CE marking and what is needed for legislation is currently under discussion in the European Commission (EGDS, see section 4.3.1)

The new European Chemicals regulation which came into force on 1st June 2007 will also have an influence on chemicals used in construction products[75]. According to REACH dangerous substances shall be notified if they are contained in articles (including building materials) and are known to be released during normal and reasonably foreseeable conditions of use, even though this is not an intended function of the article, in quantities that may adversely effect human health or the environment. However the relationship between REACH and ER3 of the CPD is not clearly defined yet and further discussions regarding the implications of REACH on construction products are foreseen[76].

4. Dangerous substances (possibly emitted from building materials): substances of concern

4.1. Introduction

In the national, foreign and European documents and studies mentioned in section 2, some information is given on the most important chemical substances that can be emitted by construction products, such as:

- The European INDEX project[14] selected a series of both high priority chemicals in indoor air (i.e. formaldehyde, benzene and naphthalene are relevant for emissions from construction products) and second priority chemicals in indoor air (i.e. acetaldehyde, toluene, xylenes and styrene). Furthermore, also some chemicals requiring further research were identified (i.e. ammonia, limonene and alpha-pinene)
- The European THADE project[15] identified the main health determinants related to indoor air quality in dwellings; formaldehyde, mould, VOCs, man-made mineral fibres and radon are relevant for building materials
- The European Paint Directive (2004/42/EC) sets limits on the VOC content of certain paints and varnishes[77].
- European pre-standard prEN 15052 specifies minimum requirements for VOC emissions from resilient, textile and laminate floor coverings.
- Within the BUMA project that started in 2006, a comprehensive database with quantified emitted compounds by construction products will be set up and a classification of the major emissions from building materials into the indoor environment and of the related building materials will be carried out[12].
- In the Belgian Federal Plan on Product Policy the following construction products and related health aspects are mentioned: hard floor coverings, glues and paints & varnishes (VOCs, heavy metals)[21].
- The Flemish Indoor Environment Decree sets quality standards for following chemical substances of relevance for construction products: acetaldehyde, other aldehydes (total), asbestos, benzene & formaldehyde. The standardised biological substances of relevance in HEMICPD project are micro-organisms & fungi[25].
- Within the study "Elaboration of a Flemish policy on the indoor environment"[29], a priority list has been worked out of which the following are important in the case of building materials: VOCs (benzene,..), formaldehyde, fine dust and asbestos. For completeness also following substances are mentioned: acetaldehyde, dichloroethane, trichloroethylene, vinylchloride, PCP (pentachlorophenol), PAHs and some mineral fibres, while important biological agents are mites, fungi, bacteria and pollen.

- In the Flemish report "Product Policy in the Context of Indoor Environment Quality"[38] an inventarisation was made of the existing product and indoor policy documents in 8 different countries; in this report a selection of 14 indoor contaminants was made which are considered as very important in Belgium: The relevant chemical substances are formaldehyde, 1,2,4-trimethylbenzene, alphapinene, toluene, methyl-di-isocyanate, glycolethers, D-limonene, benzene, acetaldehyde, vinylchloride, trichloroethylene and brominated flame retardants.
- Germany has published the LCI list (AgBB), which contains a total of 168 LCI-values for VOCs (8 VVOC and SVOCs)[78]. France (AFSSET) has recently published a similar list of (214 in 2006) 165 (in 2009) LCI-values for VOCs[79]. These lists of chemical substances (VOCs) can be classified in following groups:
    1. Aromatic hydrocarbons
    2. Aliphatic hydrocarbons
    3. Terpenes
    4. Alcohols (aliphatic & aromatic)
    5. Glycols, glycolethers & glycolesters
    6. Aldehydes
    7. Ketones
    8. Acids
    9. Esters and lactones

  For more details of these two procedures see section 8.
- The Californian CREL list (Chronic Reference Exposure Levels) contains 80 pollutants[80].
- The priority health aspects and contaminants within the French National Environment and Health Plan (PNSE) are VOCs, formaldehyde, radon radiation, artificial mineral fibres and chemical substances such as carcinogenic, mutagenic, reprotoxic and persistent, toxic compounds[41].
- The French Observatory of the Indoor Air Quality (Observatoire QAI) has listed 70 pollutants, which are both chemical and biologic in nature. Of relevance for building materials are: aliphatic & aromatic hydrocarbons (styrene, toluene,..), terpenes, alcohols, glycolethers, esters, aldehydes, biocides, halogenated hydrocarbons, particles & fibers[81].
- etc

In the European project IRMA[82] (2003-2007) that deals with the decontamination of polluted buildings and materials - and as such indirectly linked to the emission of dangerous substances from building materials in the indoor environment - following toxic substances are identified[83,84]:

- Asbestos
- Synthetic mineral fibres
- PAH (polycyclic aromatic hydrocarbons)
- PCB (polychlorinated biphenyls)
- BTEX (aromatic hydrocarbons)
- Wood protection agents, preservatives
- Heavy metals
- Volatile halogenated hydrocarbons

One example of VOCs emitted from particular indoor (building) materials is shown in Table 2[85]. An elaborate list of national, European and international scientific projects/studies/publications dealing with dangerous substances emitted from building materials & corresponding measuring/analysis methods is given in section 9.

Main groups of emitted compounds	Material type
Aldehydes, monohydric alcohols, terpenes, aliphatic hydrocarbons (single and branched chain), aromatic hydrocarbons, chlorophenol	Wood, plywood, block board, particle board, flax board, fiberboard, products made of bark and cork
Terpenes, aliphatic hydrocarbons, aldehydes, aromatic hydrocarbons	Floor wax
Aliphatic hydrocarbons, terpenes, esters, ketones, monohydric alcohols, aromatic hydrocarbons	Lacquers
Aldehydes, halogenated aliphatic hydrocarbons, aromatic hydrocarbons, aliphatic hydrocarbons, esters	Glues
Alcohols, glycols, esters	Water based adhesives
Aromatic hydrocarbons, alcohols, esters	Epoxide adhesives
Aromatic hydrocarbons, alcohols, esters, ketones, ethers, halogenated aliphatic hydrocarbons	Paints
Aldehydes, terpenes	Acrylic paints
Aromatic hydrocarbons, phenols, pyridene, quinoline	Coal tar used as binding agent in paints
Aromatic hydrocarbons, aldehydes, monohydric alcohols	Enamels and impregnantes
Aliphatic hydrocarbons, aromatic hydrocarbons, terpenes, aldehydes, ketones, esters, alcohols	Vinyl floors and tiles
Aliphatic hydrocarbons, aromatic hydrocarbons, cresols, and some components of xylamites	Insulating boards and mineral wool
Aliphatic hydrocarbons,aromatic hydrocarbons, monohydric alcohols, aldehydes, ketones, cresols, amines	Wall panelling made of PVC, polystyrene, and urea-formaldehyde and melamine resins
Aliphatic hydrocarbons, terpenes, aldehydes, ketones, esters, alcohols, aromatic hydrocarbons	Linoleum, rubber floor materials and synthetic floors
Aldehydes, aromatic hydrocarbons, aliphatic hydrocarbons, amines, halogenated aliphatic hydrocarbons, ethers, terpenes, esters, alcohols	Textile materials, carpeting, decorative materials, and furniture textiles

Table 2: Volatile organic compounds emitted from particular (building) materials[85]

4.2. Database on legislation on dangerous substances in construction products

The URL http://ec.europa.eu/enterprise/construction/cpd-ds/ from the European Commission (DG Enterprise construction) contains an overview of the dangerous substances which fall under the legislation of the different countries in the European Union ("regulated (dangerous) substances").

This database is currently being updated by the different member states. An updated document describing the Belgian legislation on DS is given in Annex 1: Belgian legislation on DS - construction.

4.3. Indicative list of dangerous substances from EGDS

The European Commission and its Expert Group on Dangerous Substances in the field of construction products (EGDS) have compiled a list of dangerous substances on which CEN/TC 351 and EOTA PT9 should focus on first, when assessing the availability and the need for developing harmonised test methods. This list is a *compilation* of all existing national and harmonised *legislation* concerning construction products.

It should be further emphasized that it is an “evolving” list, “new” substances might be added in the future.

The list “indoor air” comprises[86]:

1. **Very volatile, volatile and semi volatile organic compounds** (VVOC/VOC/SVOC: see 4.4)

- VVOC e.g. Formaldehyde; substances according to definition in 4.4 (vide infra): aliphatic hydrocarbons, aliphatic alcohols, amines, esters and aldehydes
- VOC e.g. benzene, styrene, phenolic compounds, substances according to the definition in 4.4: aromatic hydrocarbons, aliphatic hydrocarbons, terpenes, amines, aliphatic alcohols and ethers, aromatic alcohols, glycols, glycolethers, aldehydes, ketones, acids, esters and lactones, chlorinated hydrocarbons, siloxanes, isothiazolones (CIT/MIT/BIT), phenols, cresols, naphthalene.
- SVOC: substances according to the definitions in 4.4: phthalates, aliphatic hydrocarbons, organophosphorous compounds

2. **Biocides, flame retardants and other organic substances for which content-based restrictions or bans exist**

- Pentachlorophenol (PCP)
- DDT (p,p’-dichlor-2,2-diphenyl-1,1,1-trichlorethane)
- Wood preservatives
- 16 Polycyclic aromatic hydrocarbons (PAH)
- Polychlorinated biphenyls (PCB)
- Polybrominated diphenylethers:pentabromodiphenylether, octadibromodiphenylether and decabromodiphenylether*
- Azodyes
- Di(2-ethylhexyl)phthalate (DEHP)
- Polyhalogenated dibenzo-p-dioxins and polyhalogenated dibenzofuranes
- Perfluoroctanesulfonate (PFOS)

3. **Inorganic substances**

- Ammonia
- Halogens: chloride and fluoride

4. **Metals**

- Cadmium and its compounds
- Arsenic
- Copper
- Lead
- Mercury
- Chromium
- Chromium (VI)

5. Particles

- Asbestos: actinolite, amosite, anthophyllite, chrysotile, crocidolite and tremolite
- Synthetic vitreous (silicate) fibres

6. Radiation

Note: *Decabromodipheylether is a substance currently considered for a PBT (persistent, bioaccumulative, toxic) classification under REACH.

A list of the regulated volatile organic compounds excluding CMR-substances of category 1 and 2 is given in annex 12.2[87]. A list of the carcinogenic VOCs is given in annex 12.3. The list of carcinogenic VOCs is compiled from Directive 76/769/EEC by selecting (C_6-C_{16}) substances from this Directive.

4.3.1. EGDS status

The EGDS has been working on a harmonized model structure for addressing formaldehyde release in harmonised products standards. In this way all product standards will have the same solution for dealing with formaldehyde[88].
Mandate M/103 (thermal insulation products) is one of the mandates being selected as "example for indoor air" on how to amend the existing mandates for ER3 implementation[89].
After including technical and editorial comments on mandate M/103 and M/119 (floorings) provided by the SCC, these mandates will be sent to the 98/34 Committee on 13 April 2010 before asking CEN officially to provide work programmes for these three product groups.
The EGDS is also finalizing the procedural aspects for dealing with the WT/WFT concept[90].
Finally the EGDS is also starting the work on defining technical classes within the framework of the CPD to ensure that the information accompanying CE marking is clear and reduces the complexity to allow users of construction products to make fast and well-founded decisions.

4.3.2. CEN/TC 351 (WG2) status

A questionnaire for the productTCs was developed to inventory specific information per product group and to refine the list of DS[91]. In short, the questionnaire asks for specifications on what products are dealt with by the group, the intended use of these products, any emission of concern and what standards are used today. The (first) responses were collected and described in Technical Report 2[92,93]. A summary of these findings is also given in section 10.1. An overview of the other TRs which are being drafted in CEN/TC 351 is given in section 3 (vide supra).

In September 2007 WG2 has decided to prepare a horizontal standard which will specify the procedure for the determination of the emission of dangerous substances into indoor air by using the existing standards and by proposing complements to these standards with additional statements, if needed[94]. At the moment the horizontal draft standard based on expert opinions is developed and ready to start the validation process[95].

4.3.3. EOTA PT9 status

The Joint Working Group PT9-UEAtc has developed a guidance document in relation to ER3 for the use of writers of ETAGs/CUAPs and ETAs[96]. The charts described in this document show the process that has to be followed in considering dangerous substances for products/kits for which mandates for guidelines (ETAGs/CUAPs) have been given to EOTA.

The criteria for assessment and verification are listed in EOTA Technical Report 034: "General ER 3 Checklist for ETAGs/CUAPs/ETAs - Content and/or release of dangerous substances in products/kits" (edition July 2009)[97].

Based on this the EOTA WGs and CUAP writers have to create the appropriate implementation instrument. This can be either a special product related EOTA TR "checklist...in products/kits XYZ" taken into account the products which are falling under the scope of the ETAG/CUAP or incorporate the chosen related paragraphs from EOTA TR034 directly in the respective ETAG or CUAP.

The checklist (EOTA TR034) contains the "model clauses" for consideration of dangerous substances in ETAGs/CUAPs/ETAs which have to be used in connection with the clauses given in the EOTA "Guidance to ETAG/CUAP writers" and contains two lists:

- List I: contains general clauses which are relevant for all products/components
- List II is related to special products, considering the intended use and the related release scenarios

For indoor air three scenario's are taken into account:

- IA1: product with direct contact to indoor air
- IA2: product with no direct contact with indoor air but possible impact on indoor air
- IA3: product with no contact with indoor air and no impact on indoor air

The structure of the checklist (EOTA TR034) is the following (Table 3):

Component of the product(s)/kit(s)	Material(s)/families of substances	Dangerous substances that have to be considered	Release scenario's	Model clauses for verification	Model clauses for assessing and judging	NPD option allowed
Here the product(s)/components of products will be listed according the information given in the mandate. The product(s)/component(s) of kit(s) are assigned to product families	Here the relevant material(s)/families of substance(s) will be given, for which an assessment regarding ER3 is relevant	Here the relevant dangerous substances will be listed, which the approval body has to consider	Here the relevant release scenarios related to the verification/assessment are given Scenario IA: indoor air Scenario S/W: soil/water	Here different verification methods will be given, depending on the release scenario(s); the verification methods will be given as "model clauses" for the ETAG/ CUAP writers	Here differed possibilities for assessing and judging will be given, depending on the release scenario(s). The assessment and judging clauses will be defined as "model clauses" for the ETAG/ CUAP writers	Here information is given, if the NPD option is applicable

Table 3: General structure of the EOTA checklist (EOTA TR034)

At the moment product related EOTA TRs are being drafted for several ETAGs: ETAG 003 (cold storage premise kits), ETAG021 (internal partition kits), etc.

4.3.4. ISO/TC 146 SC6 status

At international level standardization in the field of air quality is done by ISO/TC 146 "Air Quality". SC6 of ISO/TC 146 is dealing with indoor air[98]. This comprises gases, particles, odours, micro-organisms, and emissions from *building products* and furnishings. The indoor environment is defined as follows: dwellings, having living rooms, bedrooms, DIY (do-it-yourself) rooms, recreation rooms and cellars, kitchens and bathrooms; workrooms or work places in buildings which are not subject to health and safety inspections in regard to air pollutants (for example offices, sales premises); public buildings (for example hospitals, schools,

kindergartens, sports halls, libraries, restaurants and bars, theatres, cinemas and other function rooms), and also cabins of vehicles.
In contrast to CEN/TC 351 sensory testing is included in the normalization work[99].

4.4. Definition of VOC

1. According to World Health organization (WHO)[100] organic compounds used in the indoor environment are classified according to their volatility by:

VOC = organic compound whose boiling point is in the range from (50°C to 100°C) to (240°C to 260°C)
VVOC= organic compound whose boiling point is in the range from < 0°C to (50°C to 100°C)
SVOC= organic compound whose boiling point is in the range from (240°C to 260°C) to (380°C to 400°C)

2. According to a working group of the European Community (Report ECA 18) the definition of VOC is based on the retention time window in which a substance is eluted in gas chromatography[101]:

VOC= all volatile organic compounds, in a capillary column coated with 100% dimethylpolysiloxane, are eluted with a retention range between n-hexane (n-C_6) and n-hexadecane (n-C_{16}). This corresponds to a boiling point range of 50-290°C.
VVOC= all compounds which, in a capillary column coated with 100% dimethylpolysiloxane, are eluted before n-hexane
SVOC= all semi-volatile organic compounds which, in a capillary column coated with 100% dimethylpolysiloxane, are eluted with a retention range between n-hexadecane and n-docosane

These definitions are also used in the AgBB scheme[78] and in the international standard EN ISO 16000-6[102].
VOC= organic compounds within the retention range of C_6 to C_{16}.
SVOC= organic compounds within the retention range from C_{16} up to C_{22}.

Note: At the moment ISO 16000-6 is using contradictory VOC definitions: The definition "50°C-100°C to 240°C-260°C" corresponds to an analytical interval from C_6 to C_{14} (see paragraph 3.2 of EN ISO 16000-6). At another place (see paragraph 11 from EN ISO 16000-6), VOC is defined from C_6 to C_{16}. This corresponds to circa 70°C to 300°C.

3. According to 2004/42/EC[77]:

VOC= any organic compound having an initial boiling point less than or equal to 250°C measured at a standard pressure of 101,3 kPa.

4. Wolkoff et al have proposed a new definition of organic compounds in indoor air (OCIA) in the context of "reactive chemistry"[103]:
    - *Chemically non-reactive* (stable) organic compounds, e.g. octane, toluene and butanol
    - *Chemically "reactive"* organic compounds with –C=C– bonds like styrene, limonene etc that react with ozone alone or with nitrogen dioxide in presence of light to produce new oxygenated products

- Organic compounds that form chemical bond(s) to receptor-sites in the mucous membranes i.e. *biologically reactive* (e.g. formaldehyde)
- Organic compounds with (known) *toxic* properties, e.g. fungicides (e.g. PCP); these compounds are characterized by effects developed over long duration of exposure

NOTE: MVOCs= microbial volatile organic compounds, a variety of VOCs produced by moulds and bacteria[104].

In ISO 16000-5[105] a general description is given of the emission characteristics of VOC sources. A generalized overview of the emission characteristics of building materials is depicted in Figure 6.

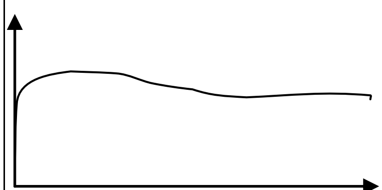
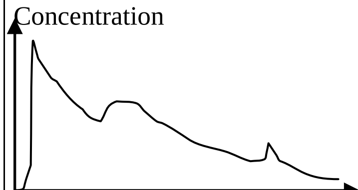
Emission characteristics and indoor air concentration	**Example of source**	**Example of emitting VOCs**
Continuous -active over a long period -uniform, short term changes in emission rates are low Concentration  	Building products -PVC -linoleum -cork -parquets and wooden furniture	 plasticizers, viscosity modifiers, solvent residues, antioxidants, stabilizers linseed oil and oxidation products as process residues binders, thermal degradation products wood extractives, solvent from varnishes, surface treatment oils and waxes
Continuous -irregular, decaying Concentration  	Paints, adhesives	Organic solvents, coalescing solvents, film forming reaction products, film degradation products" co-solvents, emulgators, defoamers, resins as colophony,

Figure 6: (generalized) Emission characteristics of VOC sources (building materials)[105]

A construction product in use can act as primary and secondary emission source for the emission of particles and/or VOCs to the indoor air:

- Primary emission: The physical release of compounds which are present in a new product
- Secondary emission: Compounds produced by chemical reaction in the product or in the indoor environment.

A schematic overview of the influence of the test conditions on primary and secondary emissions is given in Figure 7.

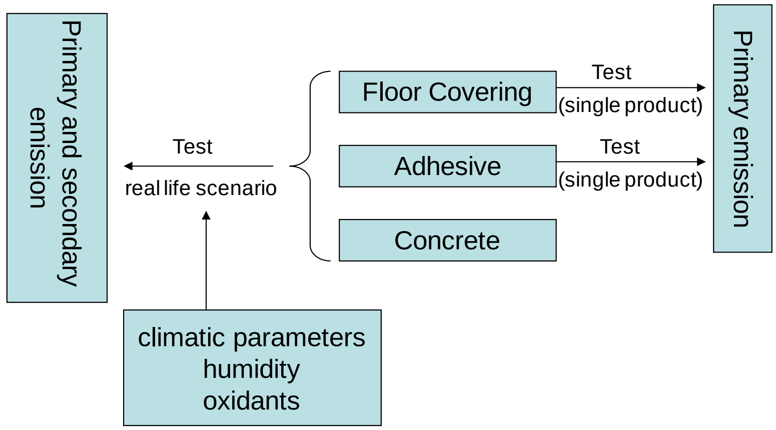


Figure 7: Influence of test conditions on primary and secondary emission (substrate-adhesive-flooring material)[106].

In Figure 8, the generation of primary and secondary emissions from building products is described[107]. Three different cases can be distinguished:

1. An unwanted reaction is happening during the production of a material and the formed reaction product is released at the customers site.
2. An unwanted reaction is happening at the surface or in different materials at the customers site, e.g. between concrete, adhesive and flooring material (see Figure 7)
3. An unwanted reaction of primary compounds with other primary compounds or reactive gases is happening in the gas phase at the customers site.

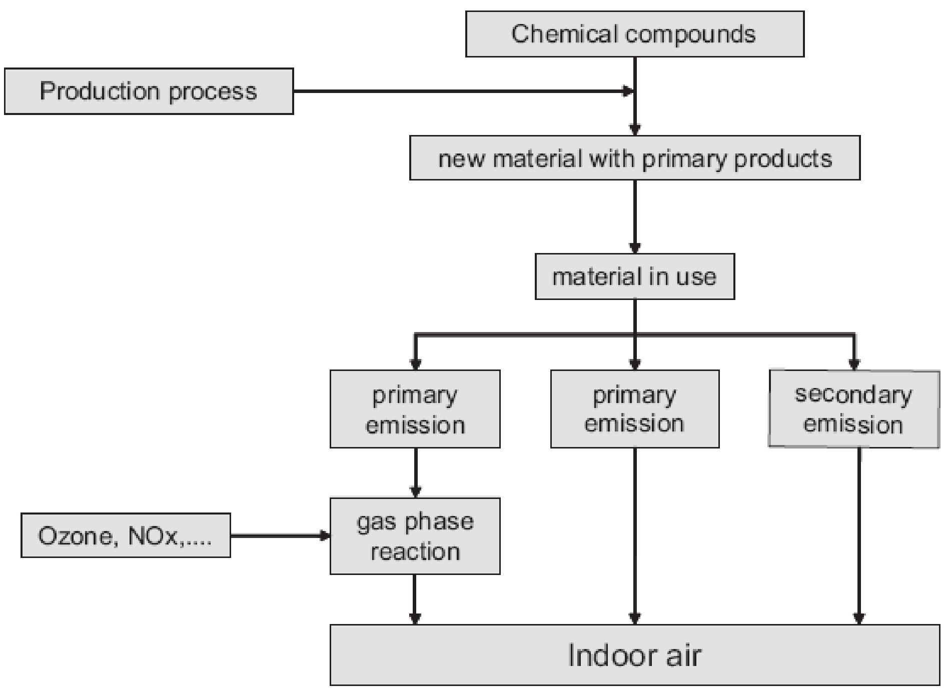


Figure 8: Formation of primary and secondary emissions from chemical constituents of (building) materials for indoor use[107].

5. Testmethods/standards/analysis methods for VOCs and PM

A proper implementation of Council Directive 89/106/EEC on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products (Construction Products Directive, CPD), requires common test concepts and measuring methods to close out threats to human health and the environment (in this case: indoor air) from construction works. The necessary concepts and methods should allow the functioning of the Internal Market for construction products and the compliance of construction works with the level of protection laid down in regulatory requirements of Member States and the EU. Hence the need for selection and adjustment or development (if needed) of appropriate testmethods for the determination of the emission of VOCs and particulate matter (PM) from construction products into indoor air. In this section an overview will be given of the available testmethods/standards & analysis methods in the field of VOC and PM emissions into indoor air.

5.1. Methods for VOCs

In the following table an overview is given of the existing/available methods/standards for VOC determination. The list is based on the work done in CEN/TC 351 WG2 with additions & updates[108].

ISO 16000-6 (2004)	Indoor air - Part 6: Determination of volatile organic compounds by active sampling on tenaxTA sorbent, thermal desorption and gas chromatography using MS/FID	Analysis of VOCs based on GC/MS: emissions testing
EN ISO 16000-9 (2005)	Indoor air - Part 9: Determination of the emission of volatile organic compounds from building products and furnishing emission – Emission test chamber method	Replaces ENV 13419-1 (1999)
EN ISO 16000-10 (2005)	Indoor air - Part 10: Determination of the emission of volatile organic compounds from building products and furnishing emission – Emission test cell measurement	Replaces ENV 13419-2 (1999)
EN ISO 16000-11 (2005)	Indoor air - Part 11: Determination of the emission of volatile organic compounds from building products and furnishing emission –	Replaces ENV 13419-3 (1999)

	Sampling, storage of samples and preparation of test specimens	
ISO 16000-1 (2004)	Indoor air – Part 1: General aspects of sampling strategy	
ISO 16000-2 (2004)	Indoor air – Part 2: Sampling strategy for formaldehyde	
ISO 16000-3 (2001)	Indoor air – Part 3: Determination of formaldehyde and other carbonyl compounds – Active sampling method	Specific method for the determination of formaldehyde
ISO 16000-4 (2004)	Indoor air – Part 4: Determination of formaldehyde – Diffuse sampling method	
ISO 16000-5 (2007)	Indoor air – Part 5: Sampling strategy for volatile organic compounds (VOCs)	
ISO 16000-8 (2007)	Indoor air – Part 8: Determination of local mean ages of air in buildings for characterizing ventilation conditions	
ISO/DIS 16000-12	Indoor air - Part 12: Sampling strategy for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polycyclic aromatic hydrocarbons (PAHs)	
ISO/DIS 16000-14	Indoor air - Part 14: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) - Extraction, clean-up and analysis by high-resolution gas chromatography/mass spectrometry	
ISO/DIS 16000-23	Indoor air -- Part 23: Performance test for evaluating the reduction of formaldehyde concentrations by sorptive building materials	Standard for measuring sorption effect

ISO/DIS 16000-24	Indoor air - Part 24: Performance test for evaluating the reduction of volatile organic compounds and carbonyl compounds without formaldehyde concentrations by sorptive building materials	Standard for measuring sorption effect
ISO/WD 16000-25	Indoor air - Part 25: Determination of the emission of semi volatile organic compounds for building products - Micro chamber method	Micro-chamber method (for routine testing)
EN 717-1 (2004)	Wood-based panels – Determination of formaldehyde release – Part 1: Formaldehyde emission by the chamber method	Steady state concentration of formaldehyde of wood-based panels
EN 717-2 (1994)	Wood-based panels – Determination of formaldehyde release – Part 2: Formaldehyde release by the gas chamber method	
EN 717-3 (1996)	Wood-based panels – Determination of formaldehyde release – Part 3: Formaldehyde release by the flask method	
EN 120 (1997)	Wood-based panels – Determination of formaldehyde content – extraction method called the perforator method	
ENV 1250-1 (1994)	Wood preservatives – Methods for measuring losses of active ingredients and other preservative ingredients from treated timber – Part 1: Laboratory method for obtaining samples for analysis to measure losses by evaporation to air	
NBN EN 1014-3 (1997)	Wood preservatives - Creosote and creosoted timber - Methods of sampling and analysis - Part 3: Determination of the benzo(a)pyrene content of creosote	Content testing based on HPLC

NBN EN 1014-1 (1995)	Wood preservatives - Creosote and creosoted timber - Methods of sampling and analysis - Part 1: Procedure for sampling creosote:	
NBN EN 1014-2 (1996)	Wood preservatives - Creosote and creosoted timber - Methods of sampling and analysis - Part 2: Procedure for obtaining a sample of creosote from creosoted timber for subsequent analysis	
PD CR 14244 (2001)	Durability of wood and wood based products – recommendations for measurement of emissions to the environment from treated wood in service	
PD CEN/TR 14283 (2003)	Durability of wood and wood-based products. Quantitative determination of pentachlorophenol in wood. Gas chromatographic method	
NEN 7331 (2007)	Bitumen and bitumen containing materials – Determination of the content of polycyclic aromatic hydrocarbons (PAH) and of benzene, toluene, ethylbenzene and xylene (BTEX) – Gas-chromatographic method with mass spectrometric determination	
EN ISO 17985 (2005)	Paints and varnishes – Determination of the volatile organic compound content of low VOC emulsion paints (in-can VOC)	Content
ISO 10283 (2007)	Binders for paints and varnishes – Determination of monomeric diisocyanates in isocyanate resins	
EN ISO 11890-2 (2006)	Paints and varnishes – Determination of volatile organic compound (VOC) content – Part 2: Gas	

	chromatographic method	
DIN VDI 4300-4 (1997)	Indoor air-pollution measurement – Measurement strategy for PCP and – hexachlorocyclohexane (lindane) in indoor air	
DIN VDI 4300-7 (2001)	Indoor air pollution measurement – Measurement of the indoor change rate	
DIN VDI 4301-2 (2000)	Measurement of indoor air pollution – Measurement of PCP and yhexachlorococyclohexane – GC/MS method	
DIN VDI 4301-3 (2003)	Measurement of indoor air – Measurement of PCB and y-HCH – CG/ECD method	
EN ISO 16017-1 (2000)	Indoor, ambient and workplace air – Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography – Part 1 : Pumped sampling	Gives guidance on sorbent use (annex D & E)
EN ISO 16017-2 (2003)	Indoor, ambient and workplace air – Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography – Part 2 : Diffusive sampling	
Önorm M 5700-1 (2002)	Determination of indoor air pollutants –	

	Gas chromatographic determination of organic compounds – Part 1 : Fundamentals*	
Önorm M 5700-2 (2002)	Determination of indoor air pollutants – Gas chromatographic determination of organic compounds – Part 2 : Active sampling by accumulation on activated charcoal – Solvent extraction	
Önorm M 5700-3 (2004)	Determination of indoor air pollutants – Gas chromatographic determination of organic compounds – Part 3 : Active sampling by accumulation on sorbents – Thermal desorption	
EN 13999-1 (2003)	Adhesives – Short term method for measuring the emissions properties of low-solvent or solvent-free adhesives after application – Part 1 : General procedure	Standard specifically for adhesives
EN 13999-2 (2002)	Adhesives – Short term method for measuring the emission properties of low solvent or solventfree adhesives after application – Part 2 : Volatile organic compound	
EN 13999-3 (2002)	Adhesives – Short term method for measuring the	

	emission properties of low solvent or solventfree adhesives after application – Part 3: Determination of volatile aldehydes	
EN 13999-4 (2002)	Adhesives – Short term method for measuring the emission properties of low solvent or solventfree adhesives after application – Part 4: determination of volatile diisocyanates	
NEN 6951 (2005)	Air – Umbrella standard for the determination of selected elements in ambient atmospheres	
EN 13694 (2004)	Suspended ceilings – Requirements and test methods	Section 4.5 of this standard refers to hygiene, health and environment – toxic gases and dangerous substances
EN 14412 (2004)	Indoor air – Diffusive samplers for the determination of concentrations of gases and vapours – Guide for selection, use and maintenance	
DIN 55666 (1995)	Determining the equilibrium concentration of formaldehyde in a small test chamber when released from coatings, melamine foams and textiles	
NF P 01-010 (2004)	Qualité environnementale des produits de construction - déclaration environnementale et sanitaire des produits de construction	Of importance for indoor air is section 7 “Contribution du produit à l’évaluation des risques sanitaires et de la qualité de vie à l’intérieur du bâtiment” (section 7.2.1: ”Contribution à la qualité sanitaire des espaces intérieurs”) & Annex A: “Données utiles à l’évaluation des caractéristiques sanitaires”

ISO 17734-1 (2006)	Determination of organonitrogen compounds in air using liquid chromatography and mass spectrometry - Part 1: Isocyanates using dibutylamine derivatives	
ISO 17734-2 (2006)	Determination of organonitrogen compounds in air using liquid chromatography and mass spectrometry - Part 2: Amines and aminoisocyanates using dibutylamine and ethyl chloroformate derivatives	
ISO 16702 (2001)	Workplace air quality - Determination of total isocyanate groups in air using 2-(1-methoxyphenyl)piperazine and liquid chromatography	
Nordtest Report TR 438 (1999)	Round Robin - Chemical emission testing by use of FLEC	
Nordtest Report TR 506 (2002)	Consensus meeting on chemical testing of emission from building products	
Nordtest method NT Build 484 (1998)	Building materials: emission of volatile compounds- On-site measurements with Field and Laboratory Emission Cell (FLEC)	
Nordtest method NT Build 482 (1998)	Building materials: emissions testing using the CLIMPAQ	Emissions measurements using specific test chamber "CLIMPAQ"
Nordtest Report TR 598 (2006)	Harmonized methods for assessment of release of dangerous substances from construction products - Nordic status	Evaluation of the importance of harmonizing test methods for regulates substances in the Nordic countries
IAQ Section, Environment Health Laboratory Branch, Division of Environmental and Occupational Disease Control, California Department of Health Services	Standard practice for the testing of volatile organic emissions from various sources using small-scale environmental chambers (supercedes previous versions of small-scale	

(2004)	environmental chamber testing portion of California Specification 01350)	
Research Triangle Institute (RTI) (under a Cooperative Agreement with EPA) (1999)	Large chamber test protocol for measuring emissions of VOCs and aldehydes	
ASTM D 5116 (2006)	Standard guide for small-scale environmental chamber determinations of organic emissions from indoor materials/products	Primary ASTM method for emissions testing using small chamber
ASTM D 6670 (Reapproved 2007)	Standard guide for full-scale chamber determination of volatile organic emissions from indoor materials/products	Primary ASTM method for emissions testing using large chamber
ASTM D 7143 (2005)	Standard guide for Emission cells for the determination of volatile organic emissions from indoor materials/products	Primary ASTM method for emissions testing using FLEC
ASTM D 5172	Test method for determination of formaldehyde and other carbonyl compounds in air (active sampler methodology)	
ASTM D 9196	Standard practice for selection of sorbents, sampling and thermal desorption analysis procedures for VOCs in air (and material emissions chambers)	
ASTM D 6330 (2003)	Standard practice for the determination of VOCs (excluding formaldehyde) emissions from woodbased panels using	

	small environmental chambers under defined test conditions	
ASTM D 6803 (2007)	Standard practice for testing and sampling of VOCs (including carbonyl compounds) emitted from paint using small environmental chambers	
ASTM D 6177 (2003)	Standard practice for determining emissions profiles of VOCs emitted from bedding sets	
ASTM E 1333 (2002)	Standard method for determining formaldehyde concentrations in air and emission rates from wood products using a large chamber	
ASTM D 5582 (2006)	Standard test method for determining formaldehyde levels from wood products using a dessicator	
ASTM D 3960 (2005)	Standard Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings	
ASTM D 6886 (2003)	Standard Test Method for Speciation of the Volatile Organic Compounds (VOCs) in Low VOC Content Waterborne Air-Dry Coatings by Gas Chromatograpy	
ASTM D 6007 (2002)	Standard Test Method for determining formaldehyde concentration in air from wood products using a small scale chamber	
ASTM WK 7215	(New) Standard Test Method for Volatile Organic Compound (VOC) Content in Waterborne	

	Coatings by Static Headspace Sampling	
ASTM WK 3464	(New) Standard test method for determination of VOCs in carpet using a specific sorent tube and thermal desorption/gas chromatography	
ASTM WK 2618	(New) Standard practice for analysing emissions from carpet using small environmental chambers	
ASTM WK 2617	(New) Standard practice for environmental chamber determinations of indoor-relevant emissions of VOCs and aldehydes from small samples of building products	
ASTM WK 3118	(New) Standard practice for determination of VOC emission factors from spray-applied rigid polyurethane cellular plastic thermal insulation using small chambers under defined test conditions	
ASTM WK 3119	(New) Standard practice for determination of VOC emission factors from sealant products using small environmental chambers under defined test conditions	
National Research Council Canada: NRC-CNRC (1997)	Characterization and quantification of volatile organic compounds in emissions from building materials for dynamic chamber tests	

National Research Council Canada: NRC-CNRC (1997)	A proposed standard practice for determination of volatile organic compounds emissions from surface coatings using small scale environmental chambers under defined test conditions	
California Dept of Health Services (2004)	The Collaborative for high performance schools (CHPS) Section 01350	Standard practice for the testing of volatile organic emissions from various sources using small-scale environmental chambers
AFSSET (2006)	Risques sanitaires liés aux composés organiques volatils dans l'air intérieur	French contribution to European discussion
Greenguard Environmental Institute (2007)	Method for measuring chemical emissions from various sources using dynamic environmental chambers	
LQAI - Laboratory of indoor air quality (Laboratório da Qualidade do Ar Interior) (2000)	LQAI Scheme on evaluation of emission from flooring materials	
GOLV Branschen, Industry Protocol (2004, 2nd edition)	Measuring the emission characteristics of composite floor structures	Test procedure for measuring the emission characteristics of **composite floor structures** and for making measurements of the emissions of individual components in a composite floor structure in order to be able to compare their contributions
NBN EN 689 (1995)	Workplace atmospheres - Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy	
EN 14041 (2004)	Resilient, textile and laminate floor coverings - Essential characteristics	See prEN 15052
prEN 15052 (2006)	Resilient, textile and laminate floor coverings – Evaluation and requirements of volatile organic compounds (VOC)	This European standard specifies an evaluation procedure based on requirements for the

	emissions	emissions of volatile organic compounds of resilient, textile and laminate floor coverings (excluding formaldehyde) . These floor coverings can be supplied in either title, roll or plank form.
AgBB – Ausschuss zur gesundheitlichen Bewertung von Bauprodukten (2005)	Health-related Evaluation Procedure for Volatile Organic Compounds Emissions (VOC and SVOC) from Building Products	German contribution to European discussion – Basis for prEN 15052
DIBt – German approval body (2006)	Implementation of health and environmental criteria in technical specifications for construction products (Research report 200 62 311 / UBA-FB 000794/e)	Regulatory approval guidelines for the health assessment of construction products, including the AgBB-scheme. The guidelines are separated in two parts, one general part for all construction products, one specific for floorings and adhesives
Federal Environmental Agency (Umweltbundesamt) (2007)	Requirements to construction products on environment and health – Identification and evaluation of VOC emissions and odour exposure (Research report 202 62 320 / UBA-FB 001002)	
Federal Environmental Agency (Umweltbundesamt) (2003)	Untersuchung und Ermittlung emissionarmer Klebstoffe und Bodenbeläge	
ISO 12460-1 (2007)	Wood based panels – determination of formaldehyde release – Part 1: Formaldehyde emission by the 1-cubic-metre chamber method	Specific for determination of formaldehyde emissions of wood-based panels
ISO/DIS 12460-2 (2006)	Wood-based panels - Determination of formaldehyde release - Part 2: Small-scale chamber method	
ISO/DIS 12460-3 (2006)	Wood-based panels - Determination of formaldehyde	

	release - Part 3: Gas analysis method	
ISO/DIS 12460-4 (2006)	Wood-based panels - Determination of formaldehyde release - Part 4: Desiccator method	
JIS A 1911 (2006)	Determination of the emission of formaldehyde for building materials and building related products – large chamber method	
JIS A 1901 (2003)	Determination of the emission of volatile organic compounds and aldehydes for building products- small scale chamber method	
JIS A 1902-1 (2006)	Determination of the emission of volatile organic compounds and aldehydes for building products - Sampling, preparation of test specimens and testing condition – Part 1: Boards, wallpaper and floor materials	
JIS A 1902-2 (2006)	Determination of the emission of volatile organic compounds and aldehydes for building products - Sampling, preparation of test specimens and testing condition – Part 2: Adhesives	
JIS A 1902-3 (2006)	Determination of the emission of volatile organic compounds and aldehydes for building products - Sampling, preparation of test specimens and testing condition – Part 3: Paints and coating materials	
JIS A 1902-4 (2006)	Determination of the emission of volatile organic compounds and aldehydes for building products - Sampling, preparation of test specimens and testing condition – Part 4: Heat-insulating material boards	
JIS A 1964 (2005)	Indoor air - Sampling strategy	

	for volatile organic compounds (VOCs)	
JIS A 1966 (2005)	Indoor air - Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography - Pumped sampling	
JIS A 1967 (2005)	Indoor air - Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography - Diffusive sampling	
JIS A 1968 (2005)	Indoor air - Sampling and analysis of volatile organic compounds by solvent desorption/capillary gas chromatography - Pumped sampling	
JIS A 1969 (2005)	Indoor air - Sampling and analysis of volatile organic compounds by solvent desorption/capillary gas chromatography - Diffusive sampling	
JIS A 1460 (2001)	Building boards - Determination of formaldehyde emission - Desicator method	
JIS A 1965 (2007)	Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA(R) sorbent, thermal desorption and gas chromatography using MS/FID	
JIS X 6936 (2005)	Information technology -- Office equipment -- Measurement of ozone, volatile organic compounds and dust emissions rate from copiers, printers and multi-function devices	
German Association of Motor	Thermal desorption of organic	German car industry method

Manufacturers Methods (VDA - Verband der Automobilindustrie: Method VDA 278	emissions from car trim components	
German Association of Motor Manufacturers Methods (VDA - Verband der Automobilindustrie: Method VDA 276-1	Measuring emissions from car trim components using a $1m^3$ chamber at 65°C	German car industry method
NVN 2792 (1985)	Ambient air quality - Determination of vinyl chloride concentration using adsorption onto porapak followed by thermal desorption / gas chromatography analysis.	
NVN 2774 (1986)	Ambient air quality - Determination of the concentration of phenols by adsorption onto Tenax followed by thermal desorption / gas chromatography analysis.	
NVN 2796 (1985)	Ambient air quality - Determination of acrylonitrile concentration using adsorption onto porapak followed by thermal desorption / gas chromatography analysis.	
NVN 2797 (1986)	Ambient air quality - Determination of the concentration of volatile esters by adsorption onto a sorbent tube followed by thermal desorption / gas chromatography analysis.	
EU Colloborative Action on Indoor Air Quality - Report N°2 (1986)	Guideline for the determination of steady state concentrations in test chambers	
EU Colloborative Action on Indoor Air Quality - Report N°6 (1989)	Strategy for sampling chemical substances in indoor air	

EU Colloborative Action on Indoor Air Quality - Report N°8 (1991)	Guideline for the characterization of VOCs emitted from indoor materials and products using small test chambers.	
EU Colloborative Action on Indoor Air Quality - Report N°13 (1993)	Determination of VOCs emitted from indoor materials and products.	
EU Colloborative Action on Indoor Air Quality - Report N°14 (1994)	Sampling strategies for volatile organic compounds in indoor air	
EU Colloborative Action on Indoor Air Quality - Report N°16 (1995)	Determination of VOCs emitted from indoor materials and products.	
EU Colloborative Action on Indoor Air Quality - Report N°18 (1997)	Evaluation of VOC emissions from building products - solid flooring materials	
EU Colloborative Action on Indoor Air Quality - Report N°19 (1997)	Total volatile organic compounds (TVOCs) in indoor air quality investigations.	
EU Colloborative Action on Indoor Air Quality - Report N°19 (2005)	Harmonisation of indoor material emissions labelling systems in the EU	Inventory of existing schemes
UK Health and Safety Executive Standard: MDHS 2 (1981)	Acrylonitrile in air. Laboratory method using porous polymer adsorption tubes and thermal desorption with gas chromatographic analysis	
UK Health and Safety Executive Standard: MDHS 3 (1981)	Generation of test atmospheres of organic vapors by the syringe injection technique. Portable apparatus for laboratory and field use	
UK Health and Safety Executive Standard: MDHS 4 (1981)	Generation of test atmospheres of organic vapors by the permeation tube method. Apparatus for laboratory use	
UK Health and Safety Executive Standard: MDHS 22 (1983)	Benzene in air. Laboratory method using porous polymer adsorbent	

	tubes, thermal desorption and gas chromatography	
UK Health and Safety Executive Standard: MDHS 23 (1988 Revised)	Glycol ether and glycol acetate vapors in air. Laboratory method using Tenax™ sorbent tubes, thermal desorption and gas chromatography	
UK Health and Safety Executive Standard: MDHS 33 (1987)	Adsorbent tube standards. Preparation by the syringe technique loading.	
UK Health and Safety Executive Standard: MDHS 33/2 (1997)	Sorbent tube standards. Preparation by the syringe injection technique	
UK Health and Safety Executive Standard: MDHS 40 (1984)	Toluene in air. Laboratory method using pumped porous polymer adsorbent tubes, thermal desorption and gas chromatography	
UK Health and Safety Executive Standard: MDHS 43 (1985)	Styrene in air. Laboratory method using porous polymer diffusive samplers, thermal desorption and gas chromatography.	
UK Health and Safety Executive Standard: MDHS 50 (1985)	Benzene in air. Laboratory method using porous polymer diffusion samplers, thermal desorption and gas chromatography.	
UK Health and Safety Executive Standard: MDHS 53/2 (2003)	1,3-Butadiene in air. Laboratory method using pumped samplers, thermal desorption and gas chromatography.	
UK Health and Safety Executive Standard: MDHS 55 (1986)	Acrylonitrile in air. Laboratory method using porous polymer diffusion samplers, thermal desorption and gas chromatography	

UK Health and Safety Executive Standard: MDHS 60 (1987)	Mixed hydrocarbons (C_3 to C_{10}) in air. Laboratory method using pumped porous polymer and carbon sorbent tubes, thermal desorption and gas chromatography.	
UK Health and Safety Executive Standard: MDHS 63/2 (2005)	1,3-Butadiene in air. Laboratory method using diffusive samplers, thermal desorption and gas chromatography	
UK Health and Safety Executive Standard: MDHS 66 (1989)	Mixed hydrocarbons (C_5 to C_{10}) in air. Laboratory method using porous polymer diffusion samplers, thermal desorption and gas chromatography	
UK Health and Safety Executive Standard: MDHS 70 (1990)	General methods for sampling airborne gasses and vapors	
UK Health and Safety Executive Standard: MDHS 72 (1992)	Volatile organic compounds in air. Laboratory method using pumped solid sorbent tubes, thermal desorption and gas chromatography.	
UK Health and Safety Executive Standard: MDHS 80 (1995)	Volatile organic compounds in air. Laboratory method using diffusive solid sorbent tubes, thermal desorption and gas chromatography.	
UK Health and Safety Executive Standard: MDHS 89 (1998)	Dimethyl sulphate and diethyl sulphate in air. Laboratory method using thermal desorption, gas chromatography-mass spectrometry.	
US National Institute of	Volatile organic compounds -	

Occupational Safety and Health (NIOSH) - Method 2549 (1996)	(screening) using multibed sorbent tubes, thermal desorption, gas chromatography and mass spectometry	
US National Institute of Occupational Safety and Health (NIOSH) - Work in progress	Volatile organic compounds - (quantitative) using multibed sorbent tubes, thermal desorption, gas chromatography and mass spectometry	
United Environmental Protection Agency EPA method 24	Determination of volatile matter content, water content, density, volume solids and weight solids of surface coatings	
United Environmental Protection Agency EPA method 311	Analysis of hazardous air pollutant compounds in paints and coatings by direct injection into a GC	
United Environmental Protection Agency (EPA)-Method TO-1 (1999)	Method for the Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Tenax® Adsorption and Gas Chromatography/Mass Spectrometry (GC/MS)	Determination of VOCs by GC/MS; Sample collection by Tenax solid sorbent
United Environmental Protection Agency (EPA)-Method TO-2 (1999)	Method for the Determination of Volatile Organic Compounds (VOCs) in Ambient Air by Carbon Molecular Sieve Adsorption and Gas Chromatography/Mass Spectrometry (GC/MS)	Determination of VOCs by GC/MS; Sample collection by molecular sieve sorbent
United Environmental Protection Agency (EPA)-Method TO-3 (1999)	Method for the Determination of Volatile Organic Compounds in Ambient Air Using Cryogenic Preconcentration Techniques and Gas Chromatography with Flame	Determination of VOC by GC/FID; Sample collection by cryotrap

	Ionization and Electron Capture Detection	
United Environmental Protection Agency (EPA)- Method TO-4A (1999)	Determination of Pesticides and Polychlorinated Biphenyls in Ambient Air Using high Volume Polyurethane Foam (PUF) Sampling Followed by Gas Chromatographic/ Multi-Detector Detection (GC/MD)	Determination of pesticides/PCBs by GC/MD; Sample collection by polyurethane foam
United Environmental Protection Agency (EPA)- Method TO-5 (1999)	Determination of Aldehydes and Ketones in Ambient Air Using High Performance Liquid Chromatography (HPLC)	Determination of aldehydes/ketones by HPLC; Sample collection by impinger
United Environmental Protection Agency (EPA)- Method TO-6 (1999)	Determination of Phosgene in Ambient Air Using High Performance Liquid Chromatography (HPLC)	Determination of phosgene by HPLC; Sample collection by impinger
United Environmental Protection Agency (EPA)- Method TO-7 (1999)	Method for the Determination of N-nitrosodimethylamine (NDMA) in Ambient Air Using Gas Chromatography	Determination of anilines by GC/MS; Sample collection by adsorbent
United Environmental Protection Agency (EPA)- Method TO-8 (1999)	Method for the Determination of Phenol and Methylphenols (Cresols) in Ambient Air Using High Performance Liquid Chromatography	Determination of phenols by GC/MS; Sample collection by impinger
United Environmental Protection Agency (EPA)- Method TO-9A (1999)	Determination of Polychlorinated, Polybrominated And Brominated/Chlorinated Dibenzo-p-Dioxins And Dibenzofurans In Ambient Air	Determination of dioxins by GC/MS; Sample collection by polyurethane foam
United Environmental Protection Agency (EPA)- Method TO-10A (1999)	Determination Of Pesticides And Polychlorinated Biphenyls In Ambient Air Using Low Volume Polyurethane Foam (PUF) Sampling Followed By Gas	Determination of pesticides/PCBs by GC/MS; Sample collection by polyurethane foam

	Chromatographic/Multi-Detector Detention (GC/MD)	
United Environmental Protection Agency (EPA)-Method TO-11A (1999)	Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Performance Liquid Chromatography (HPLC)	Determination of aldehydes/ketons by HPLC; Sample collection by adsorbent
United Environmental Protection Agency (EPA)-Method TO-12 (1999)	Method for the Determination of Non-methane Organic Compounds (NMOC) in Ambient Air Using Cryogenic Preconcentration and Direct Flame Ionization Detection (PDFID)	Determination of NMOC by FID; Sample collection by canister or on-line
United Environmental Protection Agency (EPA)-Method TO-13A (1999)	Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Ambient Air Using Gas Chromatographic/Mass Spectrometry (GC/MS)	Determination of PAHs (SVOC) by GC/MS; Sample collection by polyurethane foam
United Environmental Protection Agency (EPA)-Method TO-14A (1999)	Determination Of Volatile Organic Compounds (VOCs) In Ambient Air Using Specially Prepared Canisters With Subsequent Analysis By Gas Chromatography	Determination of nonpolar VOCs by GC/MS & GC/MD; Sample collection by specially-treated canister
United Environmental Protection Agency (EPA)-Method TO-15 (1999)	Determination of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed By Gas Chromatography Mass Spectrometry (GC/MS)	Determination of (polar/nonpolar) VOCs by GC/MS; Sample collection by specially-treated canister
United Environmental Protection Agency (EPA)-Method TO-16 (1999)	Long-Path Open-Path Fourier Transform Infrared Monitoring Of Atmospheric Gases	Determination of VOCs by FTIR; Sample collection by open path monitoring
United Environmental Protection Agency (EPA)-Method TO-17 (1999)	Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling Onto Sorbent Tubes	Determination of nonpolar VOCs by GC/MS (FID,etc); Sample collection by single/multi-bed adsorbent
ECMA-328 (2006)	Determination of Chemical Emission Rates from Electronic Equipment	
BIFMA M7.1 (2007)	Standard test method for determining VOC emissions	

	from office furniture systems, components and seating	
BIFMA X7.1 (2007)	Standard for formaldehyde and TVOC emissions of low-emitting office furniture systems and seating	

Table 4: Overview of available test methods for the determination of VOC emissions (and content)

More details on the most relevant test methods/protocols mentioned in Table 4 are given in sections 8 and 9, as well as ongoing developments of new test methods.

5.2. Methods for PM

In the following table an overview is given of the existing/available methods/standards for PM determination.

Method/standard	Scope/title	Principle
EN 15051 (2006)	Workplace atmospheres - Measurement of the dustiness of bulk materials - Requirements and reference test methods	
DIN VDI 4300-8 (2001)	Measurement of indoor air pollution- Sampling of house dust	
Önorm M 9405 (1993)	Determination of asbestos concentration in air	
ISO 7708 (1995)	Air quality – particle size fraction definitions for health-related sampling	
ISO 16000-7 (2007)	Indoor air – Part 7: Sampling strategy for determination of airborne asbestos fibre concentrations	
JIS X 6936 (2005)	Information technology – Office equipment – Measurement of ozone, volatile organic emissions and dust emissions rates from copiers, printers and multi-	Combination of VOC and “dust” measurements

	function devices	
ECMA-328 (2006)	Determination of chemical emission rates from electronic equipment	Combination of VOC and “dust” measurements
Danish Society of Indoor Climate (ICL, 1997)	Standard Test Method for the Determination of Particle Emission from Building Products	
ISO/DIS 16000-13	Indoor air - Part 13: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) - Collection on sorbent-backed filters	
NPR-CEN/TR 15230 (2005)	Workplace atmospheres – Guidance for sampling of inhalable, thoracic and respirable aerosol fractions	
ISO 15202-1 (2000)	Workplace air - Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry - Part 1: Sampling	
ISO 15202-2 (2001)	Workplace air - Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry - Part 2: Sample preparation	
ISO 15202-3 (2004)	Workplace air - Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry - Part 3: Analysis	
ISO 16740 (2005)	Workplace air - Determination of hexavalent chromium in airborne particulate matter - Method by ion chromatography and spectrophotometric measurement using diphenyl	

	carbazide	
US National Institute of Occupational Safety and Health (NIOSH)	Measurement of fibers	Use of PCM, PLM, electron microscopy, SEM, TEM & optical detection (light scattering)
US National Institute of Occupational Safety and Health (NIOSH)	Determination of airborne crystalline silica	
California Environmental Protection Agency – Air resources Board (2006)	Standard operating procedure for the determination of elemental concentrations in ambient air by energy-dispersive X-ray fluorescent (XRF) spectroscopy	
United Environmental Protection Agency (EPA)-Method IO-1.1 (1999)	Determination of PM10 in Ambient Air Using the Andersen Continuous Beta Attenuation Monitor	
United Environmental Protection Agency (EPA)-Method IO-1.2 (1999)	Determination of PM10 in Ambient Air Using the Thermo Environmental Inc. (formerly Wedding and Associates) Continuous Beta Attenuation Monitor	
United Environmental Protection Agency (EPA)-Method IO-1.3 (1999)	Determination of PM10 in Ambient Air Using a Continuous Rupprecht and Patashnick (R&P) TEOM® Particle Monitor	
United Environmental Protection Agency (EPA)-Method IO-2.1 (1999)	Sampling of Ambient Air for Total Suspended Particulate Matter (SPM) and PM10 Using High Volume (HV) Sampler	
United Environmental Protection Agency (EPA)-Method IO-2.2 (1999)	Sampling of Ambient Air for PM10 Using an Andersen Dichotomous Sampler	
United Environmental Protection Agency (EPA)-Method IO-2.3 (1999)	Sampling of Ambient Air for PM10 Concentration Using the Rupprecht and Patashnick (R&P) Low Volume Partisol® Sampler	
United Environmental Protection Agency (EPA)-	Calculations for Standard Volume	

Method IO-2.4 (1999)		
United Environmental Protection Agency (EPA)- Method IO-3.1 (1999)	Selection, Preparation and Extraction of Filter Material	
United Environmental Protection Agency (EPA)- Method IO-3.2 (1999)	Determination of Metals in Ambient Particulate Matter Using Atomic Absorption (AA) Spectroscopy	
United Environmental Protection Agency (EPA)- Method IO-3.3 (1999)	Determination of Metals in Ambient Particulate Matter Using X-Ray Fluorescence (XRF) Spectroscopy	
United Environmental Protection Agency (EPA)- Method IO-3.4 (1999)	Determination of Metals in Ambient Particulate Matter Using Inductively Coupled Plasma (ICP) Spectroscopy	
United Environmental Protection Agency (EPA)- Method IO-3.5 (1999)	Determination of Metals in Ambient Particulate Matter Using Inductively Coupled Plasma/Mass Spectrometry (ICP/MS)	
United Environmental Protection Agency (EPA)- Method IO-3.6 (1999)	Determination of Metals in Ambient Particulate Matter Using Proton Induced X-Ray Emission (PIXE) Spectroscopy	
United Environmental Protection Agency (EPA)- Method IO-3.7 (1999)	Determination of Metals in Ambient Particulate Matter Using Neutron Activation Analysis (NAA) Gamma Spectrometry	
United Environmental Protection Agency EPA (2006)	Standard Operating Procedure for the Determination of Hexavalent Chromium In Ambient Air Analyzed By Ion Chromatography (IC)	
Greenguard protocol for PM		The particle emissions are tested in a duct test stand, which simulates the flow conditions in a typical supply air duct

Table 5: Overview of available test methods for the determination of PM emissions

A comparison between the different emission standards is given in Table 6.

area	no.	measuring substance	sample	temperature (°C)	relative humidity (%RH)	Air exchange rate (1/h)	loading factor
EU	ISO/DIS12460	HCHO	Wood based materials	23	50	1	1.0 m^2/m^3
	ISO16000-9	VOC	Building material		50		
	ECMA-328	VOC	Electric device Office machine			0.5-2	0.05-0.4 m^3/m^3
		VOC, O_3, Particles				4	
German	Blue Angel Mark BAM test method	VOC, O_3, Particles	Multifunction devices, copier, printer	23	50	1-5 (<5m^3) 1-2 (>5m^3)	0.01-0.25 m^3/m^3
	VDA 276	VOC	Auto mobile interiour unit/assembly unit	65	5	400	
				100	-	440	
USA	ASTM E1333	HCHO	Wood based material	25	50	0.5	
	ASTM D6670	VOC	Any products of indoor use				
	ASTM D5116	VOC	Interiour material and wood based material				
Japan	JIS-A1901	VOC, aldehyde	Building material	28	50	0.5	2.2 m^3/m^3
	JIS-A1911	HCHO, VOC	Furniture, building materials				
	JIS-Cxxxx	VOC	PC, TV, projector	23	50	0.5 (?)	?-? m^3/m^3
	JIS-X6936	VOC, O_3, Particles	Multifunction devices, copier, printer	23	50	1-5 (<5m^3) 1-2 (>5m^3)	0.01-0.25 m^3/m^3

Table 6: Comparison of the emission measurement standards

5.3. General trend and important differences between available methods

Many standards are available that deal with VOC determination. The biggest denominator of these available methods is the use of a "test reactor" (Different sizes and shapes are available: FLEC, CLIMPAQ, desiccator,...). The organic vapours - emitted from the building materials – in the exhaust stream of the emission "test reactor" are pumped onto standard thermal desorption tubes containing usually Tenax sorbent. The sorbent tubes are then thermally desorbed, in a reverse flow of carrier gas, using a thermal desorption apparatus. During the thermal desorption, the VOCs are transferred efficiently into a capillary GC column for subsequent GC/MS(/FID) analysis. Most standards/protocols make use of an analysis for VOCs based on or similar to ISO 16000-6. For aldehydes - of which formaldehyde is of specific importance due to health reasons – the analysis is based on or is similar to ISO 16000-3. As shown in section 8, the ISO 16000 series is the most widely accepted standard for emission testing. Important to note is the recent initiation of a working draft study for the development of a new standard (ISO/WD 16000-25), the so called micro chamber method, which supports the research efforts in the project HEMICPD on this new type of test chambers (micro chamber).

However, specifically for wood based panels another standard has been developed, the EN 717 series, which has the same acceptance/impact as the ISO 16000 series. The EN 717 series differs in some key points from the ISO 16000 series as demonstrated by Table 7. Furthermore, the EN 717 principles are being used in new international standards namely ISO 12460-1 (chamber testing based on EN 717-1 principle), ISO/DIS 12460-2, ISO/DIS 12460-3 and ISO/DIS 12460-4.

	EN 717	EN ISO 16000
Origin		
Legal status	EN	EN
Based on		ECA report 18
Product types covered	Mainly wood-based panels	All relevant to indoor air
Sampling and test specimen preparation	EN 717-1	ISO 16000-9
Test chamber size	12, 1 and/or 0.225 m^3	Test chamber ISO 16000-10 Test cell ISO 16000-11
Test chamber conditions	EN 717-1	ISO 16000-10/11
- temperature	23˚C ± 0.5	23˚C ± 2
- rel. humidity	45% ± 3	50% ± 5
- air exchange	1.0 h^{-1} ± 5%	0.5 h^{-1} ± 3%
Loading factor	1.0 m^2/m^3 ± 2%	
- flooring		0.4 m^2/m^3
- all walls		1.4 m^2/m^3
- sealants		0.012 m^2/m^3
Sample (material) size	Specified: depends on chamber	According to loading factor; depends on whether wall, floor or sealant material
Substances tested/analysed		
- analysis/VOC	-	ISO 16000-6
- analysis/aldehydes	EN 717-2/3 (acetyl-acetone method)	ISO 16000-3 (HPLC-UV)
- SVOC	-	?
- VVOC	-	?
Test duration/testing	7 to 14 days, up to 28 days	3 days and 28 days
- until steady state concentration in test chamber is reached	yes	?
- number of analysis	Twice a day for up to 28 days	Duplicate tests after 3 and 28 days
Test results		
- expressed in	µg/m^3 (concentration in chamber)	µg/m^2h (emission specific rate)

Table 7: Differences between EN 717 and ISO 16000.

From the list of compiled standards/methods it can also be derived that the focus is on primary emissions, secondary emissions are not considered (yet). In the research project HEMICPD attention will also be given to secondary emissions (influence ozone,...)

Furthermore it is important to highlight that the ISO 16000 series is originally developed for emission mechanisms of homogeneous construction (and furnishing) products in direct contact with indoor air by evaporation and/or diffusion mechanisms.

Most standards specify the use of Tenax adsorbent for determining VOCs. However Tenax is not suited for every type of VOCs so further investigations on adequate sorbent and technique (GC, LC,...) for the extensive list of VOCs (~LCI list of AgBB) will be carried out[109,110]. An overview demonstrating the link between adsorbent and different subclasses of VOCs is given in Figure 9.

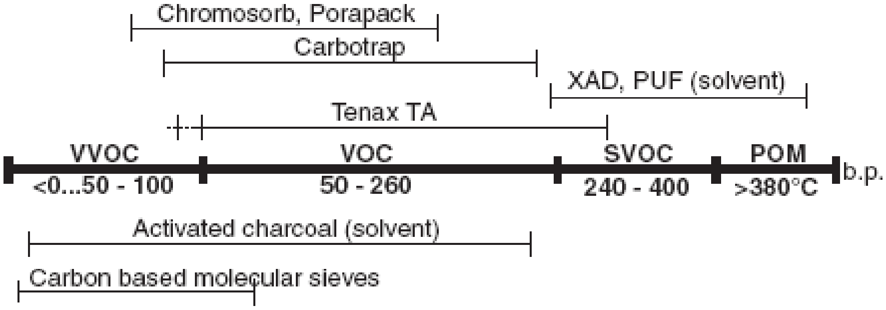


Figure 9: Applicable adsorbents for VOCs[111]

As explained in section 3 (CPD), the test situation used for the determination of emission of substances from construction products should reflect as close as possible the real in use situation. So, the test setup described in the standard for generation of emission into indoor air should be representative for the product in its intended use situation.

An overview of the in-use scenario's (for indoor air) is given in Figure 10. This figure is taken from the working document on TR2/TR4 prepared by P. Bluyssen and S. Giselsson[92].

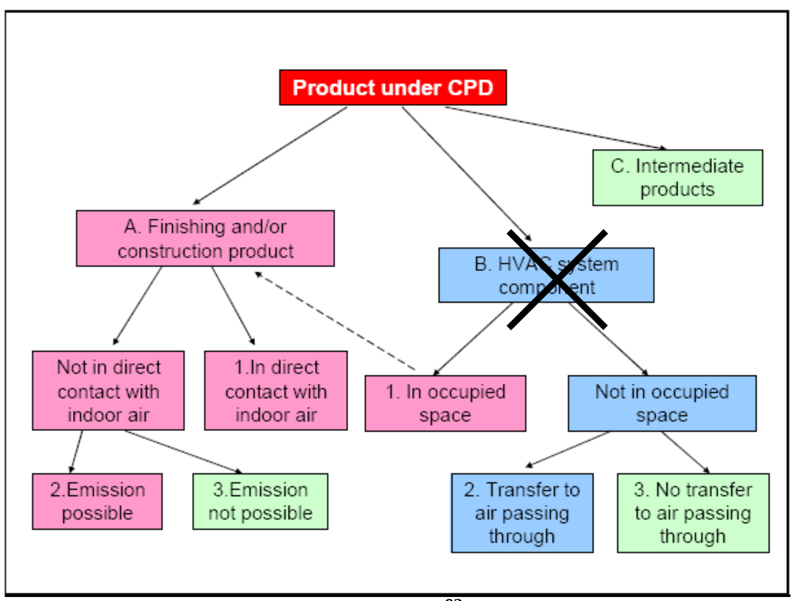


Figure 10: Products under the CPD and in-use scenario's[92]. For HVAC systems no notified regulations are presently in use. Pre-normative work is recommended on these issues[93].

From the list of compiled standards/methods it can also be derived that the available standards/methods are only for products in direct contact to indoor air. For the products falling in the category "not in direct contact with indoor air" the worst case scenario is used (direct contact with indoor air).

In Figure 10 three categories of products are identified:

- Finishing and construction products
- Heating, Ventilation and Air Conditioning (HVAC) system components

- Intermediate products e.g. additives

The research in the project HEMICPD will be “limited” to the finishing and construction products (and intermediate products).

The ISO 16000 series makes use of a model room as interpretation tool for the user of the test results. The requirement caused by the definition of a model room should be balanced with the requirements for a representative test specimen as a result of a relevant sampling plan.

Guidance for sampling, storage and preparation of test specimens is given in ISO 16000-11 or similar such as the recent Japanese standards JIS A 1902-1, JIS A1902-2, JIS A1902-3 and JIS A1902-4 for respectively boards, wallpapers & floor materials, adhesives, paints & coating materials and heat-insulating materials. It is important to note that ISO 16000-11 covers testing of “factory made” products but it is not well suited for products that require a long time to cure before they reach their final mechanical or physico-chemical properties (e.g. concrete).

For a comparison of the new harmonized CEN standard and the ISO 16000 series we refer to the annex of the scientific HEMICPD report.

Based on the work already performed in CEN/TC 351 WG2 following summary of existing standards and methods for analyses of substances on the indicative list can be given[112]:

1. Formaldehyde and other aldehydes
   Available standards:
   - ISO 16000-3
   - EN 717-1, -2, -3, EN 120, ISO/(F)DIS 12460-1,-2,-3,-4 and related methods for formaldehyde testing for E1 (wood-based panels only)
   - EN 13999-1 and -3 (adhesives only), AgBB,...

   Available techniques:
   - DNPH on silicagel / on glass fibre filters
   - Acetyl acetone method
   - Other methods: chromotropic acid procedure, pararosaniline method

2. VOC
   Available standards:
   - ISO 16000-6 (VOC & TVOC)
   - EN 13999-1 and -2 (adhesives only), prEN 15052, German AgBB, GEV, ECA report N°18,...

   Available techniques:
   - Adsorption medium (Tenax TA (for thermal desorption)
   - Activated carbon?
   - Alternatives to be used for VVOC (and SVOC)
3. VVOC (e.g. aldehydes)
   Available standards: ISO 16000-6: only limited reliability for VVOC
   - Solution 1: Different adsorbent (EN ISO 16017-1)
   - Solution 2: Low sampling flow and volume
4. Other volatiles

Methanol: EN ISO 16017-1
Ammonia: M1 test method
Isocyanates: ISO 16702 / ISO 17734-1 / EN 13999-1 and -4

5. SVOC
   ISO 16000-6: only limited reliability for SVOC
   - Solution: different adsorbent (EN ISO 16017-1): PUF,...
6. Low volatility and no volatility organic compounds
   PCP: PD CEN/TR 14283 / DIN VDI 4300-4 / DIN VDI 4301-2
   DDT
   Wood preservatives: PD CR 14244, NBN EN 1014-1/-2/-3
   PAH: NEN 7331
   PCB: ISO/DIS 16000-12, -13 / DIN VDI 4301-3
   PBDE
   DEHP
   Dioxins, furans
   PFOS
7. Particles: ICL / ISO/DIS 16000-13

Thermal desorption (TD) offers a cost-saving and high sensitivity alternative to conventional sample preparation methods for the analysis of trace level organic chemicals[113]. That is why a lot of air quality standards - and the ISO 16000 series in particular - use this method coupled with GC/MS analysis.
Samples (which are sorbent tubes containing VOCs in vapour phase) are heated in a flow of inert gas to extract target compounds into the vapour stream via a process of dynamic gas extraction.

Key advantages of TD versus solvent extraction include:

1. *Polyvalence*
   a. Detection limits are approximately three orders of magnitude more sensitive than solvent desorption / extraction methods, and even four orders of magnitude in some cases. This 1000-fold enhancement in sensitivity is the result of the inherent dilution step for the solvent extraction, what is absent with thermal desorption and makes it compatible with indoor / outdoor air control.
   b. Reliable technique: ~95% desorption efficiency or more for all of the VOCs, included polar compounds. Compared to this percentage, desorption efficiencies for most of solvent extraction are typically 75-80% at best and can be as low as 20-30% when monitoring polar analytes.

2. *Economic*
   a. No complex manual sample preparation that are labour intensive.
   b. Desorption tubes are reusable from 100 to 200 times.
   c. No solvent like CS2 is required, so no expenses for solvent treatment and air ventilation / purification are needed.

3. *Analytical improvements*

a. Solvent extraction may be susceptible of masking peaks of interest by the solvent peak. Furthermore analytical errors coming from artefacts or interference due to "impure" solvent are absent in thermal desorption methods.
b. TD offers the possibility to analyse only one part of the sample and to recollect the other part onto a new tube for confirmation or selective focusing / extraction of compounds of interest.

In brief, thermal desorption offers advantages to almost every application involving the measurement of trace level VOCs (volatile organic chemicals) and can also be used for some semivolatile determinations. It offers great versatility with regard to analyte concentration (ppt to %) and can save many hours manual sample preparation.

Although TD is highly sensitive, it cannot be used to analyse:

- Inorganic gases, except N_2O and SF_6
- Compounds which are too unstable for conventional GC analysis.
- Compounds less volatile than n-C_{40}, or 6-ring polyaromatic hydrocarbons (PAHs).
- Organics which require more than 350°C to be desorbed from the Tenax, what will cause severe degradation of the Tenax itself. In this case, the sample matrix has to be changed for another more stable at high temperature and able to desorb the organic compounds.

Table 4 (Overview of available test methods for the determination of VOC emissions) can be divided in horizontal (covering all/different products) and vertical standards (covering only one/few products)

- Horizontal standards: ISO 16000-9,-10,-11; ASTM D5116, JIS A 1901,...
- Vertical standards: EN 717-1 (wood based panels); EN 13999-1,-2,-3,-4 (adhesives); prEN 15052 (floorings),...

As can be derived clearly from Table 5, almost no methods - in contrast to determination of VOC emissions - are available for determining the PM emissions from building materials into the indoor air.
For measuring the concentration of respirable suspended particulates in the indoor environment mostly two fundamentally different instruments are commonly used: the gravimetric method and the light scattering method. These two methods are specified as alternatives in the current indoor air quality certification scheme in Hong Kong[114].
In the HEMICPD project a new test method for PM measurements on building materials will be developed based on the GRIMM monitor and ECMA-328 method.
The GRIMM 1.108 Dust Monitor (Figure 11) is an optical measuring device used for the determination of aerosols in indoor and ambient air. It is capable of measuring particles with a diameter of 0.3 to 20 µm and can divide them into different groups according to their size. From this, the different fractions (PM1, PM2,5, PM10 en TSP) can be calculated. The obtained result can be reported in different ways e.g. as particle counts (number of particles/m³) or as a mass determination (µg/m³).

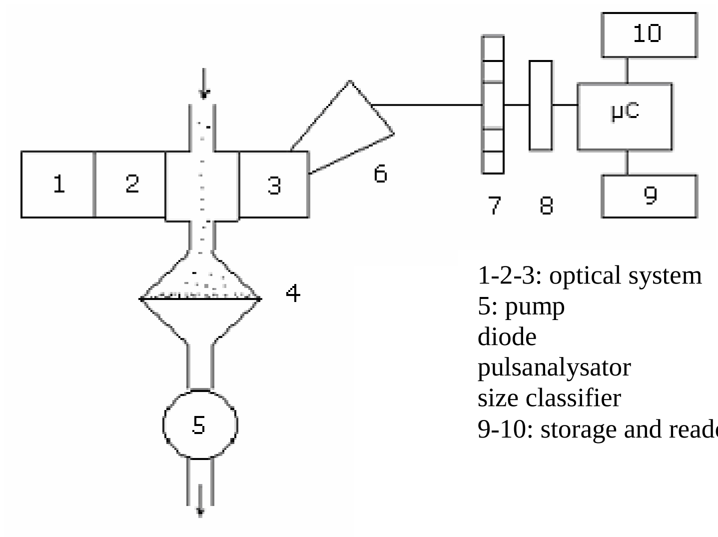
Figure 11: GRIMM 1.108 dust monitor

Figure 12 gives a schematic overview of the operation of the Grimm device. The analysed air is brought into the device by an volume controlled pump (5) with an air flow of 1.2 l/min. A laser (1, 2 and 3) sends a laser beam into this air flow and this laserlight will be scattered on the aerosols. This scattered light is detected (6) at an angle of 90° and is transformed into an electrical signal.

After amplification, this signal is divided into the different groups (8) according to the size by a pulsanalysator (7). The measured particles are captured on a filter (4) which is placed before the pump. In this way, a gravimetrical calibration of the device or a chemical analysis of the particles can be done.

The pump takes care of the necessary clean air which is is blown into the optical chamber as a mantle around the analysed air. That's how contact between the aerosol particles and the optical part is prevented. This clean air is also used for the zero calibration during the automatic calibration. This test is always executed at the beginning of a measurement.

The GRIMM 1.108 has a memory card on which the results of the measured concentrations and of the size of the particles can be logged every minute. These data are copied to a computer after the measurements.



1-2-3: optical system 4: filter
5: pump 6: diode 7: pulsanalysator 8: size classifier
9-10: storage and readout of the signal

Figure 12: Scheme of GRIMM 1.108

Specifications of the GRIMM 1.108 are given in Table 8.

particle size	0.23/0.30/0.40/0.50/0.65/0.80/1.0/1.6/2.0/3.0/4.0/5.0/7.5/10/ 15/20 µm
particle range	1 tot 2 000 000 counts/litre
mass range	0.1 tot 100 000 µg/m³
sensitivity	1 particle/litre
air flow	1.2 litre/minute
reproduceability	+/2%
operation temperature	+4°C tot 45°C
dimensions	24 x 12 x 6 cm
weight	2.4 kg
energy supply	Battery or 240 VAC

Table 8: Specifications GRIMM 1.108

6. Methods for odour determination (both quantitative and qualitative)

In the following table an overview is given of the existing/available methods/standards for odour determination.

Method/standard	Scope/title	Principle
NBN EN 13725 (2003)	Air quality - Determination of odour concentration by dynamic olfactometry	Dynamic olfactometry
NVN 2818 (2005)	Odour quality - Sensory determination of the hedonic tone of an odour using an olfactometer	Hedonic tone
ECA report N°20 (1999)	Sensory evaluation of indoor air quality	
NF P 01-010 (2004)	Qualité environnementale des produits de construction - déclaration environnementale et sanitaire des produits de construction	Of importance for indoor air is section 7 “Contribution du produit à l’évaluation des risques sanitaires et de la qualité de vie à l’intérieur du bâtiment” (section 7.3.4: ”Confort olfactive”) & Apendix A: “Données utiles à l’évaluation des caractéristiques sanitaires”
VTT Reseach Note 2262 (2004)	Sensory evaluation method of building materials for labelling purposes	
Danish Society of Indoor Climate (ICL, 2003)	Standard Test Method For Determination of the Indoor-Relevant Time-Value by Chemical Analysis and Sensory Evaluation	Combination of chemical and sensory measurements
The Building Information Foundation RTS (2004)	Emission Classification of Building Materials: Protocol for Chemical and Sensory Testing of Building Materials	Combination of chemical and sensory measurements
VDI 3882-Part2-	Olfactometry Determination of Hedonic Odour Tone	Hedonic tone
VDI 3882-Part1	Olfactometry Determination of Odour Intensity	Odour Intensity
NF ISO 5492	Analyse sensorielle-Vocabulaire	
AFNOR NFX 43-101 (1986)	Qualité de l’air-méthode de mesurage de l’odeur d’un effluent gazeux-détermination du facteur de dilution au seuil de perception.	

AFNOR NFX 43-104	Qualité de l'air-Atmosphères odorantes-méthodes de prélèvement.	
AFNOR NFX 43-103	Mesurage olfactométrique-Mesurage de l'odeur d'un effluent gazeux. Méthode supralaminaire.	Odour Intensity
NT BUILD 482	Building materials : emissions testing using the climpaq	
Austrian UZ 35	Österreichisches Umweltzeichen-Textile Fußbodenbeläge	
Natureplus label	International label	Ecological label for building materials
VDA 270	Détermination du comportement odoriférant des matériaux de l'équipement intérieur des voitures	Odour intensity
SNV 195 651	Standard	No details found
VDI 3881 part 1	Odour threshold determination: Fundamentals	
VDI 3881 part 2	Odour threshold determination: Sampling	
VDI 3881 part 3	Odour threshold determination: Olfactometers with gas jet dilution	
VDI 3881 part 4	Odour threshold determination: form and test report.	
ASTM E544-76(1981)	Stand**ar**d Practices for Referencing Suprathreshold Odor Intensity	
ASTM E544-75(1997)	Standard Practices for Referencing Suprathreshold Odor Intensity	
ASTM E544-99(2004)	Standard Practices for Referencing Suprathreshold Odor Intensity	
ISO 5725-1	Exactitude (justesse et fidélité) des résultats et méthodes de mesure – Partie 1 : Principes généraux et définitions	
ISO 5725-2	Exactitude (justesse et fidélité) des résultats et méthodes de mesure – Partie 2 : Méthode	

	de base pour la détermination de la répétabilité d'une méthode de mesure normalisée	
ASTM E-18 (1968)	Manual on sensory testing methods.	
prEN ISO 16000-9, Part 9	Détermination des émissions de composés organiques volatils de produits de construction et d'objets d'équipement. Méthode de la chambre d'essai d'émission (ancienne prEN 13419-1)	

Table 9: Overview of available test methods for the odour determination

6.1. Sensory evaluation: overview

6.1.1. Why a sensory evaluation?

Measuring only chemical emissions does not provide enough information to characterize the impact of building materials on indoor quality. Statistical analysis between single VOC and sensory assessment values confirms that is not practical to try to evaluate the odour acceptability of a building material on the basis of its emission profile[115]. Knudsen and al. also showed that building products continue to affect the perceived air quality, even when the concentrations of selected odour intensive primary VOCs were well below their respective odour thresholds[116]. Our knowledge of the interaction of odours of single compounds is also very limited. Sensory evaluation must be performed separately using human subjects as detectors, since chemical measurements can not substitute for human olfactory system, which processes the chemical stimulus resulting to a personal response[115].

6.1.2. Odour components

From physiological response point of view, odour perception can be divided in four major components: *detectability* (which corresponding to the detection threshold), *intensity*, *quality* and *hedonic tone*. This perception varies largely with the person and is influenced by a lot of factors like age, cultural context…[117]. So what panel selection is very important.

6.1.3. Selection of subjects

Some of the interlaboratory variations can be attributed to this panel differences. Therefore, European/National standardised panel selection procedures should be established. Important factors are: *sensory sensitivity, representativeness to the target population* and *personality variables*. Panels may become more comparable by training to meet common performance criteria.

Furthermore, panel members must be unbiased (occupants of problem buildings, family staff members… should not be used). The documentation of the panel should include: *gender, age, smoking habits, criteria for why some subjects may have been excluded, measures of sensory sensitivity* and *its representativeness as to a specified population*[117].

The composition of the panel depends on the purpose of the test. This purpose should be displayed. Sometimes the test panel is recommended to comprise selected, sensitive persons, at other times naive subjects are preferred. In laboratory testing there should be at least 15 persons in the panel[117].

6.1.4. Limits and quality requirements of sensory evaluations

There is a great need for improving the level of measurement in sensory evaluations. For that purpose the discipline of psychophysics provides many techniques and testing procedures for obtaining sensory data from human subjects. In order to obtain comparability between sensory evaluations, they have to be calibrated or standardised. For calibration it is necessary to use references. A number of reference chemicals have been suggested for sensory investigations of air quality (see chapter 6.7)[117].

For design and control purposes, a reasonable assumption is that the *perceived intensity of odours* plays the major role in the generation of odour discomfort. In case another attribute than perceived odour intensity is being used, e.g. odour acceptability, its psychophysical exposure-response data should be compared to perceived odour intensity data[117].

All perceived intensity measures for odour or sensory irritation should be reported also as concentration equivalents of the reference chemical being used. Some methods require that a dilution series be made of the original air sample and therefore its odour/irritation must be fairly intense to start with. These methods include the *method of limit* and the *method of constant stimulus* (see chapter 7). Therefore, they are suitable only for laboratory testing[117].

6.2. Odour components and labels/standards

A lot of labels exist but few of them include sensory evaluation in their methodology. Odour assessment labels are described below, first of all in terms of major components of the odour (detectability, intensity, quality and hedonic tone), in the chapter 6.3 in terms of methodology principles and in the chapter 6.4 in terms of tool requirements.

6.2.1. Detectability/ Odour concentration/ Sensory threshold

The odour concentration definition refers to the concept of dilution factor firstly introduced by Zwaardemaker in 1888. The underlying idea is that the higher the odour concentration is, the more the sample has to be diluted to reach the olfactory threshold. So, the odour concentration corresponds to the dilution factor which must be applied to a sample to reach the level where it does not smell anymore. The following equation translates this dilution:

$$Z = C = \frac{Vo + Vi}{Vo} = 1 + \frac{Vi}{Vo}$$

Vo odorant sample volume (gaseous phase)

Vi odourless air volume

According to this equation, the concentration corresponding to the perception threshold is 1.

In the usual sense there is no fixed odour or irritation threshold of absolute detection for a particular pollutant but rather a gradual transition from total absence to definitely confirmed sensory detection. Thus, theoretically thresholds do not represent a fixed point but a value on a continuum[118].

Classical threshold theory assumes the existence of a momentary absolute sensory threshold. Some measurements based on this concept have been made on indoor air, ventilation systems and emissions from materials[119,120].

Most threshold methods are based on dilution of the air sample until 50% of a panel no longer detects odour. The odour threshold concentration in the case of a gas mixture with a known or unknown composition can be given as a number of dilution factors, or "odour units"[119,121]. In no case do multiples of threshold values express the degree of perceived odour intensity above threshold.

Odour threshold values reported in the literature often vary considerably for the same odour substance. The reason is that threshold values are to a large extent defined by threshold measurement procedure, quality of the olfactometer, purity of the chemical substance, sample of subjects, etc.[122]. For example, if the samples are presented in ascending order the estimated detection limits are generally lower than when the samples are presented in randomised order. If the method of constant stimulus is used, detection limits will be generally higher than for the method of limits (see section 6.7).

6.2.1.1. NBN EN 13725 (2003) Air quality – Determination of odour concentration by dynamic olfactometry

The most often used standard in terms of odour concentration is the NBN EN 13725. The dynamic method applies the odour threshold as an assessment scale of the odour strength. The odour is diluted by fresh air starting at a high dilution level. The odour threshold is reached if the concentration of odour leads to an odour impression within 50% of the human panel members. The odour unit OU is deduced from the threshold dilution level: According to the EN 13725 standard, the European Odour Unit (OU_E) is defined as the amount of odorant(s) that, when evaporated into 1 cubic metre of neutral gas, elicits a response from a panel corresponding exactly to the olfactory threshold. The dynamic test procedure has been carried out by an Olfactometer.

6.2.2. Odour intensity/ Perceived intensity

Odour intensity describes how strong the odour is. A lot of labels and standards use this odour component (ICL, VDI 3882, GUT…) but the requirements can be different from a label/standard to another (see chapter 6.3 and 6.4). Stimulus which creates this perception must have a concentration above odour threshold. To draw odour intensity in terms of concentration, two psychophysical laws are usually proposed: the Weber-Fecher (1) law and the Stevens law (2).

Weber-Fechner law(1):

Weber and Fechner propose a semi-logarithmic law linking the odour intensity I to a ratio of the actual odour concentration C and the perception threshold concentration, C_0, chosen as reference. The law is valid only for $C \geq C_0$ and sufficiently far above the threshold, but not for too strong odour.

$$I = k_w \log \frac{C}{C_0}$$

I : Odour intensity

k_w : coefficient depending on units and odour nature

C : actual odour concentration

C_0 : perception threshold concentration

Semi-logarithmique relation between C and I is shown by Figure 13.

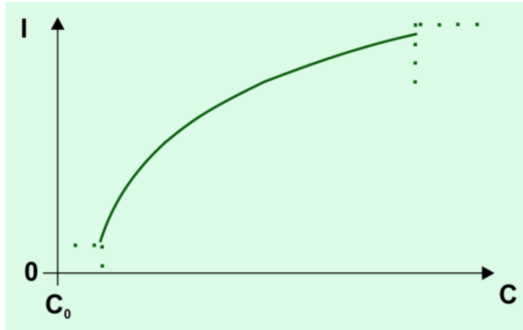


Figure 13: Relationship between odour intensity I and odour concentration C according to Weber and Fechner

Stevens law(2) :

Alternatively, Stevens propose a power law :

$$I = I_0 \left(\frac{C}{C_0} \right)^n$$

I : odour intensity
I_0 : threshold intensity
C : odour concentration
C_0: perception threshold concentration
n : Stevens exponent ($0.1 \leq n \leq 1$).

I_0 and C_0 are constant values for a given odorant.

Figure 14 shows this relation for experimental data.

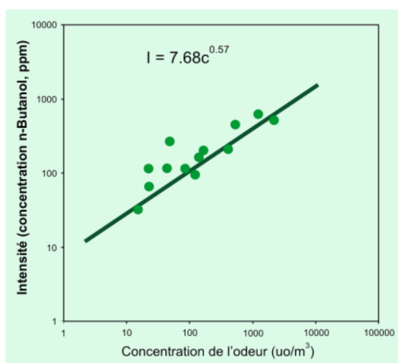


Figure 14: Double logarithmic chart showing the relationship between odour intensity and odour concentration according to Stevens

6.2.2.1. Indoor Climate Label (ICL)

The perceived odour intensity of the air is evaluated by means of a separate scale (see appendix 2). The scale has end-points and marks labelled as follows: ”no odour”, ”slight odour”, ”moderate odour”, ”strong odour”, ”very strong odour” and ”overwhelming odour”. The acceptability and intensity of the supplied air is evaluated by evaluation of the air from at least one empty test chamber. Values are assigned to the labels as follows: 0 =”no odour”, 1 =”slight odour”, 2 =”moderate odour”, 3 =”strong odour”, 4 =”very strong odour” and 5 =”overwhelming odour”. At each time of evaluation the median of the panellists’ evaluations of acceptability and odour intensity should be calculated for both the material sample and the empty test chamber. The indoor air quality is regarded as acceptable at odour intensity less than 2.

6.2.2.2. VDI 3882-Part 1: Olfactometry determination of odour intensity (see above)

6.2.2.3. NF X43-103: Mesurage olfactométrique – mesurage de l’odeur d’un effluent gazeux (see above)

6.2.3. Hedonic odour tone (acceptability)

Hedonic Odour Tone describes the pleasant or unpleasant odour components. Acceptability is also often used to described odour in building product labels.

6.2.3.1. GUT, Austrian UZ 07, Natureplus label, SNV 195 651 and VDA 270

Agrees with Swiss standard SNV 195651) Intensity varies on a scale between 1 (no odour) and 5 (very unpleasant odour). The scale has end-points and marks labelled as follows: 1 = no odour, 2 = not unpleasant, 3 = slightly unpleasant, 4 = unpleasant, 5 = very unpleasant. Intermediate values like 1,5; 2,5…are accepted. The indoor air quality is regarded as acceptable at odour intensity less than 4.

6.2.3.2. VDI 3882 Part 2 – Olfactometry determination of hedonic odour tone

Within the meaning of this Guideline, the hedonic tone of an odorant is the effect which can be ascertained according to a scale ranging from ‘extremely pleasant” to “extremely unpleasant”.

6.2.3.3. Indoor Climate Label Denmark

Odour acceptability is an evaluation of perceived air quality. Acceptability of the perceived air quality should be marked on a continuous scale, slightly modified from Gunnarsen and Fanger (1992) (see appendix 1). The scale is divided into two separate scales with clearly marked end-points ”clearly acceptable”/”just acceptable” and ”just unacceptable”/”clearly unacceptable”, respectively. The individual subject first decides whether the air quality is perceived as acceptable or unacceptable and then rate the degree of (un)acceptability. No marks are allowed between the labels”just acceptable” and”just unacceptable”. The end-point ”clearly acceptable” is assigned the value of +1, the end-point ”clearly unacceptable” the value –1, while ”just acceptable” and ”just unacceptable” are assigned the values of +0.1 and –0.1, respectively. The indoor air quality is regarded as acceptable at acceptability greater than 0.

6.2.3.4. The Building Information Foundation RTS (2004)

The subject firstly decides whether the air sample is acceptable or unacceptable and then rates the degree of acceptability. No marks are allowed between just acceptable and just unacceptable (see appendix 1). Each scale is divided into nine levels. Each level is numbered so that clearly acceptable corresponds to the numerical value **+1** and just acceptable to the value **+0.1**. Correspondingly, clearly unacceptable corresponds to **–1** and just unacceptable to **–0.1**. The accuracy of the values is 0.05. As subjects assess the air sample twice, with a panel of five members, ten numerical values are obtained from the sensory measurements. The arithmetical mean of the values is calculated, and the mean acceptability vote is presented with an accuracy of one decimal and compared to the emission classes of building materials. If the result of the five member panel does not fall between –0.4 and +0.4**,** the evaluation is repeated with ten more members resulting altogether in thirty numerical evaluation values of which the arithmetical mean is calculated. The acceptability vote of the supplied air is calculated in the same way. If the value of the test room air is ≥ 0.5, the results of the sensory measurements are acceptable. If the value is < 0.5, the odour source of the test room is removed, and the sensory measurements is repeated within one day.

6.2.4. Odour description

Adjectives (aromatic, sweetish, chemical…) are given but this description is not used to evaluate acceptance of product material. This information is valuable for the tracing of the source of odour if there are some problems with the test arrangements and to control the performance of the sensory panel.

6.2.4.1. GUT

Adjectives are given (aromatic, sweetish, chemical…) to describe material odour.

6.2.4.2. The Building Information Foundation RTS (2004)

The evaluation form also includes a column with odour descriptions. The subject is asked to choose the characteristics which best describe the odour of the air sample.

6.3. Label/standard methodology

In this section, the sensory evaluation methodology is described for each of the most used labels and standards: ICL, GUT, UZ35, Natureplus, VDA 270, SNV 195651, RTS, VDI3882 part 1 and 2, NBN13725 and AFNOR NFX 43-103.

6.3.1. Indoor Climate Label (ICL, Denmark)

Principle: ICL is based on **indoor-relevant time values** determined for building materials on the basis of chemical emissions and sensory test. Indoor-relevant time value (chemical emissions) for a product is defined as the necessary time for the slowest emitting individual chemical substance with the lowest indoor relevant odour or irritation threshold to reach half of this threshold value in a fictive standard room. The indoor-relevant time-value based on the sensory evaluations is given as the time (in days) at which the requirements for acceptability and odour intensity are fulfilled. The indoor-relevant time-value is based on the highest time-value of both the chemical and sensory tests. The time-value is given in full days and rounded up to the nearest value, which can be divided by ten.

Panel requirements: The sensory evaluation of the material emission is made by an untrained panel of at least 20 persons, who rate the air quality by marking the acceptability and odour intensity on continuous scales. The panel members should belong to the age range from 18 to 50 years. Panel members should have a normal olfactory sense. Smoking habits of each member should be noted. The sensory panel should preferably have an equal distribution of both sexes and not more than 40% smokers. The panellists should not suffer from a cold on the days of evaluation.

Panel instruction: Prior to the evaluation of the air quality in the test chambers the members of the panel should be instructed to:

- refrain from eating garlic or spicy food on the day or the day before the evaluation
- refrain from eating or smoking during the last hour prior to evaluation
- have a high personal hygiene and refrain from using strong-smelling cosmetics
- wear clothes washed in a neutral detergent.

Each panel member should be carefully instructed how to use the scales in the evaluation form. The panellists should take only one inhalation of the air to be evaluated and report their first impression of acceptability and odour intensity. In case the panellists should evaluate the air quality from more than one test chamber, they should refresh their olfactory sense by breathing clean air for at least 1 minute in between the evaluations. This is to avoid any cross adaptation.

6.3.2. GUT, Austrian UZ 35, Natureplus label and VDA 270

For carpets, this label includes chemical emissions and odour testing. The olfactory method tries to simulate the odour development at increased temperatures. For this purpose, a sample of 144cm² is thermostated during 15h in a desiccator at 37°C and 50% Hr. After sample conditioning, the team of test persons specially trained (at least 7) for this method individually assesses the resulting odour development and tries to define the type of odour as well as the ***intensity*** and the ***overall impression***. It is the primary objective of such an odour test to ensure a clear distinction between acceptable new-product odour and unacceptable odour formation. This test is based on the Swiss standard SNV 195651.

6.3.3. The Building Information Foundation RTS (Finland, 2004)

Sensory characterisation of material emissions is carried out using a two-phase sensory test. The sensory assessments are commenced with a naïve sensory panel of at least five members. If the mean acceptability vote of the panel falls outside a certain range, no further sensory testing is needed and the building material belongs either to emission class M1 or M3. If the mean acceptability vote of the panel falls within this certain range, the sensory test shall be repeated with ten more naïve subjects in order to reach a higher accuracy of the evaluation determining the sensory emission class. In this case, the mean acceptability vote is calculated using the values given by all fifteen evaluators each giving two votes. Thus the acceptability calculation is based on 30 evaluations of which the arithmetic mean is calculated.

		M1	M2
Sensory evaluation	Sensory assessment, percent of unsatisfied	<15% (result $\geq$ +0,1)	<30%
	Odour description	Not odorous	Not significantly odorous

Table 10: Sensory evaluation-RTS method (Finland)

Emission class M3 includes materials whose emissions exceed the values specified for materials in category M2.
Brick, stone, ceramic tile, glass, metal surfaces and wood hold a special status in the classification.

Panel requirements: The sensory testing may be commenced with a panel of five naive subjects. If the panel acceptability vote of this falls between –0.4 and +0.4 a second round of sensory testing with a panel of ten more members shall be done within one day.
Panel instruction: The panel assesses the acceptability of the air exhausted from the test chamber. The members of the untrained panel will be instructed to

- refrain from eating garlic on the day before sensory assessments
- take a shower in the morning of the assessment day and refrain from using strong-smelling cosmetic products
- wear odourless clothes (no leather jackets etc.)
- abstain from drinking coffee and smoking between sensory assessments and an hour before they begin

This follows the general principles used internationally concerning untrained panels. According to the protocol the *panellist is asked to imagine that he/she in the working environment would be exposed to the air* similar to that coming out of the chamber.

Procedure:

1. **Evaluation of the empty chamber-background acceptability:** First, the sensory evaluation assesses the background acceptability of the empty test chamber including the test specimen supports. When the required acceptability of minimum 0.5 is reached, the test specimen is placed into the chamber. The test specimens is conditioned for two days in the test chamber before performing the sensory evaluation.
2. **Immediate perception (Air of test room):** Then, the subjects are asked to assess the immediate perception of the air of the test room. The subject must tick either the box marked acceptable or the box marked unacceptable in the *upper right-hand corner* of the evaluation form. If 20 % or more of the subjects consider the air of the test room unacceptable, the subsequent sensory measurements is rejected and repeated when the acceptability of test room is reached.
3. **First and second assessment:** Next, the subject waits in the test room for at least two minutes before the first evaluation. The air exhausted from the test chamber is delivered to the subjects through a diffuser at an airflow rate of 0.9 l/s. The subjects are asked to place their nose slightly inside the diffuser, and after waiting for a moment, to make two or three inhalations before making the assessment. The result is ticked on the *left side evaluation colons* of the evaluation form. This assessing procedure is repeated after a two-minute pause and the result is ticked on the *right hand column*.

PS: Note that the same evaluation form is used for the assessment of both the test room air and the air exhausted from the test chamber. This is because the sensory panel is not allowed to know what it is assessing. Only two subjects may be in the test room at a time.

Calculation of the reliability in the sensory tests

In the calculation of the reliability and the accuracy of the untrained panel the Student-t-distribution calculation may be used. The sufficient previous assumption for it is that the human sensory perceptions are normally distributed. The use of the t-distribution gives a possibility to use quite small samples with known reliability and accuracy. The general reliability and accuracy calculation of the t-distribution are presented in many common handbooks of statistics.

The probable error **dx** in the t-distribution may be calculated from the following equation

(1) $dx = \pm tp(n - 1)\, s / \sqrt{n}$

where **s** is the standard deviation of the sample, **n** is the size of the sample (here the size of the panel) and **tp(n-1)** is a function of the degrees of freedom (n-1) and the selected risk to make right conclusions. This function is a useful tool and is typical for t-distribution. It has been calculated and presented in the statistical tables in nearby all standard books of statistics. These tables have calculated both for one tailed and two tailed studies or examinations. Here the one tailed consideration is selected and reasonable, because here we are not interested on the worst results in the cases with very poor results in sensory tests or on the best results in the cases with very good results.

The risk to make wrong decisions is illustrated in the next formula as a function of the sample size. **k = tp(n-1)/ √n**

From the formula above it can be seen that the coefficient k is very strongly dependent on the selected level of risk. If the risk 10 % to make a wrong decision is accepted the coefficient k with the sample size of 15 is below 0,4. With the risk level of 1 % the same coefficient (representing the accuracy) will require bigger sample than 40.

The risk is here also symmetrical. The risk that an acceptable product will be rejected is equal to the risk that an unacceptable product will be accepted.
According to the equation, the key factor for the accuracy and reliability of the sensory tests made by the untrained panel is the standard deviation of the odour sensations and acceptance of the measured odour. In the literature there exist results from large series of measurements with untrained panels made in Denmark. In these published results the standard deviation is from 0,4 to 0,6, lowest values typically in the both ends of the acceptability scale, where the judgements are naturally easier and more clear positive or negative. These values of standard deviation have also been confirmed in the sensory tests made in Finland in different institutes.

To avoid unnecessary testing costs the risk level to make wrong decision has been selected 10 % in the Finnish classification system. It is also in a good harmony with the accuracy of the chemical tests. Very important is also that the risk is symmetrical and so the risk is equal to both parts in the classification process.

Using now the equation of t-distribution and placing the values above of standard deviation **s** and the coefficient k depending on the size of the panel and the selected risk, the accuracy (the probable error) of the sensory tests with untrained panel may be calculated. With a 10%e risk, the probable error with different panel sizes are given in following table.

The values corresponding to the standard deviation 0,6 give quite realistic picture and higher estimate of the probable error and therefore they are selected to be used in the sensory acceptance procedure with untrained sensory panels in the Finnish emission classification.

Size of the untrained sensory panel	5	10	15	20
Probable error when standard deviation is 0,4	0,27	0,17	0,14	0,11
Probable error when standard deviation is 0,6	0,40	0,25	0,22	0,17

Table 11: Calculated probable error as a function of the size of the panel, with 2 different standard deviations 0,4 and 0,6 in the acceptability scale from -1 to +1 in the sensory tests with untrained panels.

For other purposes the probable error may also be calculated using the same equation. The standard deviation **s** seems to be very constant, but of course the coefficient **k** may be selected higher or lower depending on the chosen risk or panel size. For example with a risk of 1 %, instead of here chosen 10 %, the probable error 0,40 requires the panel size of 15 and similarly the probable error 0,22 requires panel size of 50 – 60, when the standard deviation is 0,6.

In the scientific research, where the "real" right values are searched, this risk factor must of course be lower. This means naturally, that the size of the sample must be much larger than in the practical classification.

The reliability of this above presented calculation has also been verified in Finland using results of sensory tests of certain materials with large panels. Smaller samples of panels of 5 and 15 members have then been selected randomly from these results. The risk to make wrong decisions with these randomly selected smaller panels have been below or in the level of the calculated 10 %. The statistical theory and the presented calculations basing on it will be seen to hold true and reliable.

6.3.4. VDI 3882 Part 2 – Olfactometry Determination of hedonic odour tone

Experience has shown that the odour threshold is not an adequate criterion for the evaluation of a highly odorous substance. Additional factors, such as the effect of an odour of above-threshold concentration, i.e. the increase in olfactory sensation in consequence of increasing odorant concentration, as well as its hedonic odour tone, i.e. its position on the pleasant- unpleasant" scale, must also be taken into account.

General boundary conditions: If possible, the origin of the samples should not be disclosed to the members of the panel in order to ensure that their evaluation is conditioned only by the immediate situation. There must be no suggestion of any situations which could detract from the situation in which evaluation takes place.

Panel: the panel has to consist of at least 15 persons on account of the interindividual differences which may occur when determining hedonic odour tone. The panel member's sensitivity is not a criterion for the panel selection.

Olfactometer: Requirements laid down in guideline VDI 3881 Parts 1, 3 and 4 are applicable.

Concentration range: The range of concentration to be presented to the panel members for hedonic odour tone evaluation must be determined beforehand by means of a preliminary odour threshold test. The concentrations to be presented to the panel members comprise a range of 6 dilution steps wich differ by a factor of approximately 2. The lower limit must correspond to the panel threshold. In the case of low odorant concentrations a smaller number of dilution steps may be presented. If necessary, the test may be confined to the undiluted test gas.

Presentation of stimuli: The presentation of odour tone stimuli is done at random. With this method, the dilution steps are presented in any desired sequence for each series of measurements. Adaptation effects must moreover be minimized by ensuring that an above-threshold odour stimulus is not presented for longer than 15 seconds, with an allowance of an additional decision time of 5 seconds. The minimum break between any two stimuli should be at least 1 minute. A series of measurements must not commence either with a blank sample or with a maximum stimulus.

Response to stimuli: Since it is also the case that some of the concentration presented for evaluation will be below the individual threshold of certain panel members and that blank samples are also presented for control purposes, it is first of all necessary to ask the panel member whether or not he or she has perceived an odour at all. If the answer is in affirmative, the hedonic odour tone of the perceived concentration must be evaluated in accordance with the following category scale (see Figure 15)

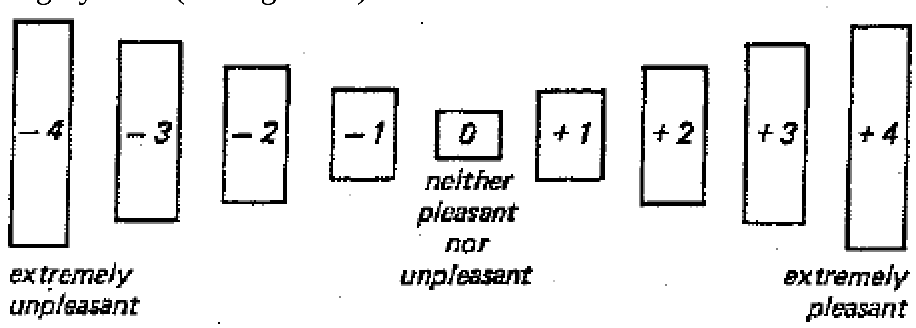


Figure 15: Category scale of hedonic odour tone

6.3.5. VDI 3882 Part 1 – Olfactometry Determination of hedonic odour intensity

Panel: Since the width of the confidence interval depends markedly on the number of panellists, the sample size (minimum number of panellists) shall be adjusted to meet the accuracy requirements imposed by the objective of the test. Not less than eight panellists shall be employed. In selecting panellists, use shall be made of experience relating to their abilities (health, tendency to guess, decisiveness) when determining odour thresholds. The sensitivity of the panellist (position of his/her individual odour threshold) is not a selection criterion.

Olfactometer: Like odour threshold determinations, intensity measurements are carried out with dynamically diluting olfactometer. The olfactometer used shall meet the following requirements in particular :

- to avoid dilution of the inhaled sample by secondary air, the air supply at the olfactometer outlet (nose mask or sniffing tube) shall not be less than 1.2. m^3/h (0.33 l/s) for breathing at rest and 2.0 m^3/h (0.56 l/s) for sniffing; at the same time, the diameter of the outlet opening shall be such that the velocity of the air supplied shall be low enough not to produce a disturbing sensation;
- steps shall be taken to ensure that the panellist is not aware of changes in the odorant concentration settings except as a result of olfactory sensations;
- the instrument shall be so designed that it can easily be cleaned in the event of any contamination due to the odorant-laden gas; the nature of the materials in the olfactometer which come into contact with the gas under investigation shall be such that surface reactions or deposits are prevented as far as possible.

Presentation of concentrations: To estimate the range of concentrations for the intensity determination, a tentative odour threshold determination shall be performed beforehand. Before the actual intensity measurement is carried out, the panellist shall then be familiarised with the odorant to be assessed by offering him/her a clearly perceptible sample.

The concentrations of the suprathreshold stimuli shall differ approximately by a factor of 2. In setting the maximum concentration offered for assessment, allowance shall first of all be made for the toxicity of the gas to be investigated and any risk to the panellists shall be eliminated.

In addition, the upper limit of the scaling shall not be exceeded so as not to excessively stress the panellists. If the stimulus response “extremely strong” is given too often, the test series shall be reduced by removing the level with the hitherto maximum concentration.

Exposure to stimuli: The exposure to the stimulus shall be carried out by the random presentation method, i.e. the sequence of the presented concentration levels is selected at random. The suprethreshold stimulus shall be supplied until the panellist makes a decision, but for not more than 15 s. The interval between the stimuli shall be not less than 1 min. The series of measurements shall be repeated (at least twice; three runs).

To prevent adaptation and habituation during exposure to the stimulus, neutral air shall be presented between the individual concentration levels. The initial stimulus presentation shall be at an average odorant concentration.

Response to stimuli: Category scaling
To assess the odour intensity of the inhaled sample, the panellist shall classify his odour impression in accordance with the concepts specified in the following scale:

Odour	Intensity level
Extremely strong	6
Very strong	5
Strong	4
Distinct	3
Weak	2
Very weak	1
Not perceptible	0

Table 12: Category scaling for intensity

The category scale used in this Guideline is primarily an ordinal number scale to whose categories a specified ranking is assigned:

Not perceptible < very weak <Weak < distinct < strong < very strong <Extremely strong.

Assuming the validity of the Weber-Fechner law, these assessment categories are assigned verbal descriptions in such a way that the entire intensity spectrum is covered at intervals which are as equal as possible. To reinforce this characteristic, numbers have been assigned to the verbal categories.

The scale is open in the upward direction. While he or she is being instructed, the panellist is told that he can carry out evaluations beyond level 6. Measurements of $I \geq 6$ are combined in category 6.

6.3.6. NBN EN 13725 (2003) Air quality – Determination of odour concentration by dynamic olfactometry

6.3.7. CSTB based on "AFNOR NFX43-103 Mesurage olfactométrique – mesurage de l'odeu d'un effluent gazeux – Méthodes supraliminaires »

This sensory evaluation classifies building products in terms of relative odour intensity. Currently CSTB propose a classification with 3 levels:

- **Classe O+** (very weak odour intensity): intensity lower than a butanol reference solution of 3,2 ppm,
- **Classe O** (weak odour intensity): intensity lower than a butanol reference solution of 32 ppm,
- **Classe O-** (strong odour intensity): intensity higher than a butanol reference solution of 32 ppm.

6.4. Tool requirements

We can also classify labels in terms of tool requirements. There are three basic testing methods: Dessicator (or similar), olfactometer and CLIMPAQ (or similar).

Classification/Label	Method	Testing after … day
Austrian UZ 35	#1-GUT	1
GUT (textile flooring)	#1-GUT	1
Natureplus	#1-Natureplus	1 or 3
French CSTB C classification	#2- (NFX43-103)	3 + 28
DICL	#3-DICL	Typically 28
Finnish M1	#3-M1	28

Table 13: Tool requirements for six labels

#1. Static odour following *SNV 195651*, *GUT*, *Austrian UZ 35*, *Natureplus label* and *VDA 270*: A test piece is stored in a dessiccator (see Figure 16) at 37°C and 90 % relative humidity. After 24 hours 3-6 test persons rate the smell using a scale that may have 3, 5 or 6 criteria. This gives a combination of odour intensity and hedonic odour character

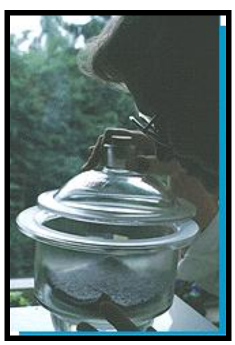


Figure 16: dessiccator

2. Dynamic odour test of air samples taken from the chamber outlet air using EN13725, NFX 43-103 or similar. The odour strength is determined by used of a **dynamic olfactometer** (see Figure 17) The results are expressed as odour units (EN13725), as concentration of a reference odorous substance (NFX 43-103), or as decipol*.

* Fanger (1988) developed a method in which the human perception is used for the assessment of the perceived indoor air quality. The goal of his method was to determine the pollution load of the indoor air based on a simple

source model. The arbitrary pollution of the room air is expressed in terms of the emissions from a standard person. This model implies a uniform behaviour of different pollution sources in terms of the perceived air quality. The pollution strength of a standard person is defined to 1 olf. The perceived air quality is used as a measure for the concentration of this pollution load in a room air and its unit is “pol”. It is defined as the perceived air quality in a space with a pollution load of 1 olf and a ventilation rate of 1 l/s. The additional unit “decipol” is more commonly used in practice. It is defined by the dilution of 1 olf by an air volume flow rate of 10 l/s.

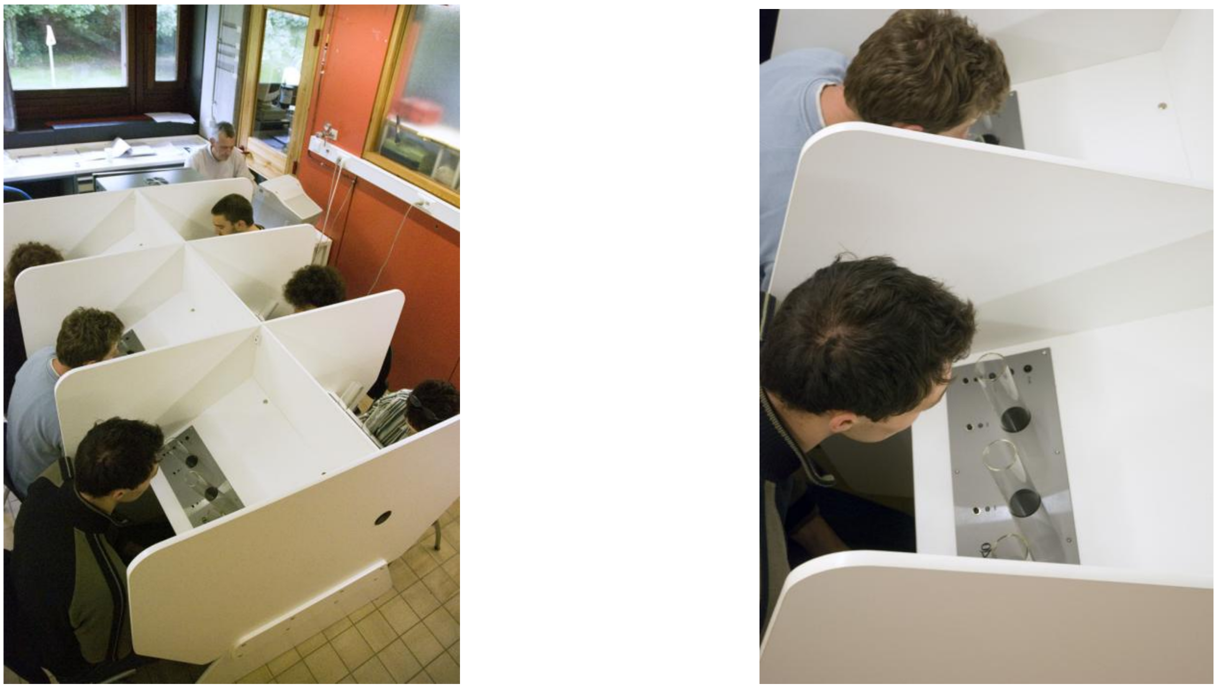


Figure 17A & B: Dynamic olfactometer

3. Dynamic odour can be test directly at the chamber outlet. The *Finnish M1 label* and *Danish ICL* use the **CLIMPAQ** (Nordtest, 1998). This is a special test chamber, which has been developed and designed for sensory evaluations of material emissions. The CLIMPAQ is made of glass and has a volume of 50.9 L. Other test chamber designs may be used for the sensory evaluations. The device to present the air to be evaluated by the sensory panel must, however, be designed according to the description given below. The device should be shaped as a funnel with the dimensions given in Table 14.

Length	450 mm
Inside diameter at outlet	80 mm
Inside diameter at inlet	25 mm

Table 14: Dimensions of a funnel

The test chamber, including the funnel, should be made of a non-emitting, chemically inert and cleaning-friendly material. Thus, the test chamber may be made of e.g. polished stainless steel or glass. For the sensory evaluations, it is important that the air extracted from the test chamber is not mixed with the ambient air. The above-mentioned funnel and a specified airflow rate through the funnel ensure this. The required air flow rate through the funnel is min. 0.9 l/s. This should be taken into account when planning the test specimen area used for the test. Outline of a test chamber for sensory evaluations of emissions is shown in Figure 18.

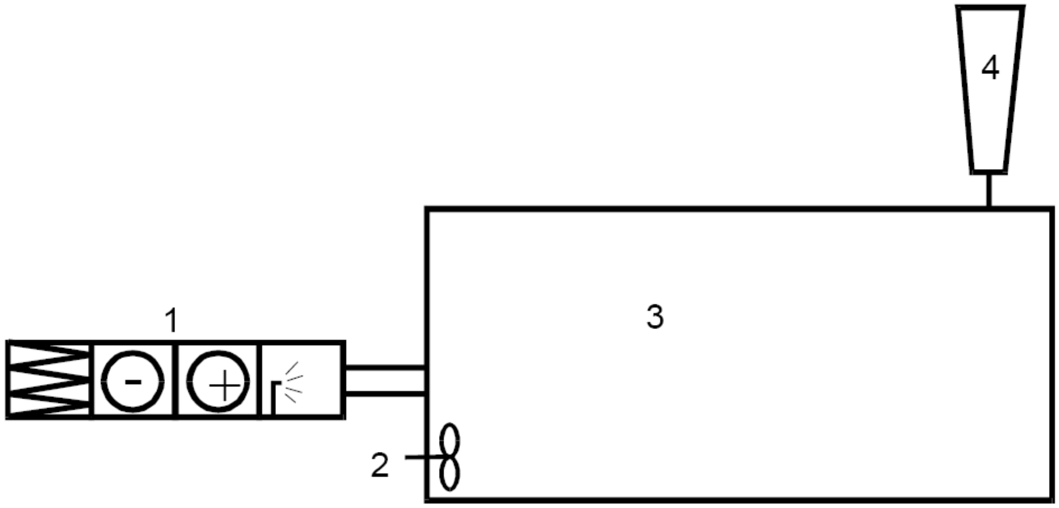


Figure 18: Outline of a test chamber for sensory evaluations of material emissions. 1: System to condition the supply air; 2: Mixing fan; 3: Test chamber space for placing test specimens; 4: Funnel providing air for sensory evaluation.

6.5. Electronic noise

An electronic nose is an array of non-specific chemical sensors, controlled and analyzed electronically, which was initially developed to mimic the action of the mammalian nose by recognizing patterns of response to vapours. The used gas sensors may be of different types, e.g. metal oxide sensors which change resistance when exposed to vapours, or quartz crystals which oscillate at different frequencies when VOCs are adsorbed on their surface. The sensors are not specific to any one vapour; they are included in an array of different sensors, each with a different sensitivity to chemical families. So, gases and gas mixtures can be identified by the pattern of response of the array.
Most existing chemical sensors are designed to detect specific molecules, but array-based sensing uses non-specific sensors in which the pattern and magnitude of response are used to identify and quantify more globally the presence of contaminants. They are trained to identify different gaseous ambiences from their specific signal patterns. Contaminants are identified and quantified by using a software analysis program such as pattern recognition and/or neural network.

Electronic Noses have been discussed by several authors and are widely applied in many different domains, such as food processing quality control, medical diagnosis, detection of explosives, identification of fragrances, …
E-nose is even applied for environmental monitoring[123] and the research group "Environmental Monitoring" at ULg was one of the pioneers in that field.

Applications of electronic noses go now far beyond the detection of odorant gas mixtures and they are applied to monitor various VOC's whether they smell or not.

In that spirit, the monitoring of indoor air quality with e-nose is only a recent emergent application. Rather few scientific papers present original works dealing with air quality in dwellings.

Some of them concern laboratory researches on artificial gas mixtures.
A study in Colorado-USA aims at extending the previous knowledge of gas sensor arrays by demonstrating their ability to detect several VOCs (toluene, heptane, acetone, ethanol, …) at concentrations typical of indoor environments[124].
Some other works concern development of sensors or optimisation of operating conditions to adapt e-noses to indoor air monitoring.
A Chinese work[125] takes advantage of capillary column selective separation and the convenience of surface acoustic wave sensors (SAW) to develop an enhanced portable gas analyser equipped with an on-line pre-concentrator. This instrument has been found capable of achieving near real-time analysis of complex VOC mixtures at several ppb levels within ten minutes and constitutes a promising potential tool for trace gas detection in indoor air. They have particularly tested dynamic signal extraction and pattern recognition techniques to enhance the instrument capabilities[126].
Such hybrid microsystem (chromatography column + tin oxide gas sensors) was also tested by an Italian team[127] to detect BTEX at trace levels (5 ppb). The system was based on a first sensor array prototype which was designed to detect CO and NO2 in simulated real indoor environment[128].
The famous research group of Udo Weimar in Tuebingen Germany[129] developed also a mobile robot equipped with gas sensors enabling some interesting applications in indoor environment, including its use as "electronic watchman" to detect pollutants in dwellings.

To progress towards field applications, it seems necessary to improve the sample uptake by pre-concentrating the analytes prior the measurement with e-nose. Various research groups develop such tools, specifically for indoor environment : for example, a Chinese team[130] and a research group from Karlsruhe in Germany[131].

Concerning more targeted applications in indoor environment, some papers presents carbon monoxide detection in buildings in the presence of possible interfering gases. It is the case for the group of University of Siena, in Italy. The aim was achieved either by miniaturising the detection system[132] or by modulating the temperature of the sensors[133]. The commercial instrument Kamina, developed by Dr Goschnick, in Karsruhe (Germany) was also applied to detect trace component in indoor environment and particularly for fire detection[134]. A Korean research group developed also an instrument able to detect combustible and explosive gas leakage in buildings[135]. The French group of CSTB compared olfactometry, chemical analysis and electronic nose techniques to study the emissions of indoor paints[136].
The "Environmental Monitoring" group at Arlon shown that it is possible to use the e-nose principle to detect the presence of solvents in dwellings[137].

Many papers concern also the detection of moulds growing on building materials, or more generally the detection of microbial volatile organic compounds (MVOCs) considered as indicators of fungal contamination. Rather than detailing all the scientific contributions regarding that subject, it should be more efficient to refer to a complete bibliographic paper published by the Arlon research group[138].

Different research project are conducted in the world about e-nose applications in indoor environment, even in very "exotic" countries, like Tasmania (Determination of Indoor Air Quality using an Electronic Nose – Project of the School of Chemistry of the University of Tasmania).

Few patents or commercial instruments exist in that field. Two patents may be mentioned. The first one (US6711470, USA, 2002) concerns a sensor array able to detect if the level or type of contaminant poses a threat or hazard to the occupants. If it is the case, the present invention takes corrective actions which may include introducing additional fresh air.
The second one (CA2125810, Canada, 1995) uses an array of only 2 gas sensor to detect contaminants in the air.

Concerning more specifically the detection of dry rod (Serpula lacrimans) in building material, an apparatus was patented by the team of Krishna Persaud, in Manchester (GB200320802, UK, 2003), one of the collaborators of the ULg research group. The instrument includes an array of gas sensor and a SPME concentrator device.

6.6. Labels/standards summarized

Table 15 and Table 16 summarize the labels and standard discussed in section 6.

Label	Odour concentration	Odour intensity	Hedonic odour tone	Odour description	Comparison empty test chamber	Intensity scale (number of values)	Values varied between …	Values for acceptability intensity	Acceptability scale (number of values)	Values varied between …	Values for acceptability intensity	Outcome
NBN 13725	1	0	0	0	0							
ICL	0	1	1	0	1	6	0 and 5	Median < 2	4	-1;-0.1; +0.1;+1	Median > 0	Indoor relevant time value
VDI 3882 (1)	0	1	0	0	0	7						
NFX 43-103	0	1	0	0	0							
GUT	0	1	0	1	0	5	1 and 5	Median < 4				
UZ35	0	1	0	0	0	5	1 and 5	Median < 4				
Natureplus	0	1	0	0	0	5	1 and 5	Median < 4				
SNV195 651	0	1	0	0	0	5	1 and 5	Median < 4				
VDA 270	0	1	0	0	0	1	0		5	1 and 5	Median < 4	
VDI 3882 (2)	0	0	1	0	0							
RTS (2004)	0	0	1	1	1				4	-1;-0.1; +0.1;+1	Median ≥ 0.5	M1/M2/M 3

Table 15: Overview of labels/standards dealing with odour determination

Label	Panel size	Trained/untrained panel	Time of conditioning	Olfactometer	Dessicator	Climpaq
NBN 13725				1	0	0
ICL	20	U		0	0	1
VDI 3882 (1)	8			1	0	0
NFX 43-103				1	0	0
GUT	7	T	15h	0	1	0
UZ35	7	T	15h	0	1	0
Natureplus	7	T	15h	0	1	0
SNV195 651	7	T	15h	0	1	0
VDA 270	7	T	15h	0	1	0
VDI 3882 (2)	15			1	0	0
RTS (2004)	5 or 15	U	2 day	0	0	1

Table 16: Overview of labels/standards dealing with odour determination (continued)

6.7. Recommended methods by ECA 20

For materials and components testing the sensory evaluation is recommended to include *detectability* and/or *perceived intensity of odour* and/or *sensory irritation*. In addition a yes-no classification should be made of whether the sample is perceived unpleasant or not, at conditions simulated to be typical for the intended use of the material[117].

6.7.1. Test requirements

Measurements of detectability and/or perceived intensity should not only be made of the test sample but also of the *reference chemical* being used. The evaluation method and results should be displayed, including *false alarms* and specification of *background air* (dilution air) *conditions*, and adequate *basic test requirements* should be met. In addition, a *qualitative characterization* of the test sample may be made[117].

6.7.2. Reference standard

The perceived odour intensity scale should be calibrated by use of a reference scale of at least five, or preferably more, concentrations of a reference odorant. The reference standard odorant should be either acetone (2-propanone), dimethyl monosulfide, hydrogen sulphide, n-butanol or pyridine. The used reference standard odorant should be traceable and should be compared with at least one other of the alternative reference odorants listed above: as to their absolute odour thresholds and their psychophysical exposure-response relationships for perceived odour intensity. In case another attribute than perceived odour intensity is being used, its psychophysical exposure-response data should be compared to perceived intensity data, e.g., in a plot of attribute-to-attribute comparisons at the same physical exposure levels. Preferably, *odour detectability* and *perceived odour intensity* may be measured jointly. All perceived intensity measures should be reported also as concentration equivalents of the reference chemical being used[117].

6.7.3. Recommended methods

When high inter-laboratory comparability, resolution power and precision are required the following methods are recommended by the group ECA 20. All of these are summarized in Table 17.

6.7.3.1. For the detection of odours

a) Method of limits

For odours the method of limits is the most direct method for establishing an absolute sensory threshold and it is based on a well established theory. In its classical form the stimuli are presented in alternating ascending and descending series starting at different points to avoid that the subject falls into a routine. The subject is required to report whether the sample can be detected or not. A response criterion is established at the start so that the experimenter will know when the presentation series is to be interrupted. The threshold value for each separate test series is defined as a point in-between the last undetected and the first detected points in the stimulus continuum.

A small-medium sized panel is required with the subjects mainly selected as to their sensitivity. There is little need for training the subjects. Typically no calibration is made but is postulated. The resulting data appear on nominal scales and, therefore, it is not meaningful to add, subtract, divide or multiply the threshold values.

b) Method of constant stimulus

Also this method has a well established theory. The method of constant stimulus (method of frequency) is based on the assumption that the momentary individual threshold value varies from time to time and that this variation has a normal distribution. The absolute odour threshold can be defined as the effect dose corresponding to an arbitrarily selected frequency of positive response, typically 50 %, "effective dose-50, ED-50". But this method is in limited use and only for single compounds.

A practical variant of an ascending method of limit with paired comparison and frequency analysis similar to that in the method of constant stimulus has been used extensively in outdoor and indoor investigations of environmental odours[122,139].

PS: A combination of the two methods may be preferred in some cases. Detection measures also can be obtained by jointly measuring detectability and perceived intensity.

c) Signal detection index, d’

The theory of signal detectability is very well established[140,141,142]. It claims that no absolute threshold exist and stresses the relationship between correct and incorrect positive responses (hits and false alarms). In signal-detection theory, sensory excitation from one and the same repeated signal is assumed to have a defined distribution. Furthermore, it is assumed that excitation from another origin than the stimulus (=signal), for example from spontaneous nervous activity (=”noise”), appears as an integrated part of the sensory response.

Various detectability indices are used to estimate the overlap of the "noise" and "signal+noise" distributions. Such indices are less influenced by guessing and lack of cooperation on the part of the subject than is the classical threshold concept.

The index d’: A frequently used detectability index is d'. In calculating this index, it is assumed that "noise" and "signal+noise" are both normally distributed along the same excitation continuum, and that these distributions have the same variance. The index d' is calculated from the proportions of hits and false alarms obtained from subjects when they are exposed to stimuli and "blanks" in irregular order, assuming that the response criterion is constant over the conditions studied. The index d' is the difference between z-scores for p (hit) and p (false alarm).

With signal detection methods the task of the subject is simple. No training of the subjects is required. However, advanced presentation equipment is needed (olfactometer) and the procedure is very time consuming. The resulting data are on interval scales and additions/subtractions are meaningful operations. No calibration is being made. The main advantage of applying the signal detection theory is that both positive and negative false responses (false alarms and misses) can be estimated. Thus, the effects of the response criterion can be separated from the sensitivity measures. Classical threshold methods typically only correct for false positive responses.

Signal-detection theory also provides methods with very short sampling time suitable for measurements of weak sensory signals[143]. However, as a relatively large number of observations are required, the signal level has to be constant for some length of time, or be repeated a large number of times with good reproducibility. The main drawback of the signal detection approach is the small range of physical quantities that can be investigated if the number of observations in the studies is to be held within reasonable limits. On the other hand the method does not require wide dilution series and, therefore, potentially is suitable for measuring weak odours as they typically appear in indoor spaces[139].

6.7.3.2. For the determination of perceived intensity of odour and/or sensory irritation

Measures for quantifying ***perceived intensity*** of odours and ***sensory irritation*** are obtained from subjects by various *psychological matching* and *scaling methods*.

a) Equal-attribute matching

Equal-attribute matching is based on a less well established theory but the reliability of similarity matching has been empirically verified. The practical usefulness of cross-modal equal-attribute matching in developing "objective" yardsticks of perceived intensity has been demonstrated for several pairs of sensory attributes.

By "*intra modality matching*" matching scales are developed within one and the same sense modality. In this technique the subject matches the subjective intensity or some other attribute of, for example, two different odorants[144]. Thus, in *cross-modality matching* the matching is performed between continua, while in intra modality matching the matching is between two qualities within one modality.

Some *cross-modal matchings* require little equipment, such as visual analogue scales (e.g. line length). Advanced equipment is required in *intra-modal matching* (olfactometer in the case of odours). The panel can be small to medium-sized and no training of subjects is required. However, the panel members should be selected as to how well they adhere to the specific performance criteria and they should belong to the assumed target population. Typically no calibration is made but is postulated. No inter-laboratory comparisons have been made. The resulting data are on *interval-ratio scales* and arithmetical operations are meaningful.

Intra-modality intensity matching has been shown to be a reliable and valid method for olfaction[145,146,147,148]. The consistency of this method in olfaction has been demonstrated in that matchings of three different chemical compounds were found transitive and symmetric with respect to odour[143]. For applied studies a time-saving method of successive approximations has been developed[149].

Equal-magnitude matching also has been used in *acceptability/preference* testing. By simultaneous exposure to two different stimuli and allowing the subjects to adjust the stimuli, they may trade one off with the other[150]. Less uncertainty is introduced since adjustments may be continuous without categories.

A continuous visual scale has been used for rating of *acceptability*[151]. The middle of the scale is defined as the transition between just acceptable and just not acceptable. Votes may therefore be interpreted both as binary votes and as votes on a continuous visual scale. This allows a conversion of the votes on the continuous scale to an estimate of the percentage of subjects voting not acceptable with reduced standard deviation compared to direct binary votes.

b) Category scaling

Category scaling is not based on a well established theory but empirically it has been shown to work at times. For example, the method has been used to scale indoor air qualities based on semantic scales. The five point intensity scale introduced by Yaglou was initially used as a category scale and later modified to be continuous[152]. Based on everyday experience subjects were asked to assign a point on the visual scale ranging from "No odour" to "Overpowering odour" to an air sample. The semantics of the category names give some information of absolute levels. Comparison of results relies however on the representativeness of the subjects and their consistent interpretation of the descriptors.

Category scaling puts little requirement on equipment and is fast to conduct. The panel size can range from small to large. No training of subjects is required. The panel usually is selected as to representativeness. Typically no calibration is made but is postulated. The data from category scaling will appear on ordinal-interval scales depending on the application.

c) Magnitude estimation with several references

In the classical form of the method, subjects are required to make direct numerical estimations of the sensory magnitudes (like perceived intensity or pleasantness) produced by different stimuli. The typical task can be: How intense/pleasant does the following series of stimuli seem to you?

Assign numbers to your subjective impression. From the numbers obtained an interval or ratio scale can be constructed. The slope (or curvature) of the psychophysical exposure-response function tells how fast responses change with stimulus intensity.

Magnitude estimation using several references is a well established method for specific applications. For IAQ measurements a semi-advanced equipment is required as well as a small- to medium-sized panel. Sometimes training to anchors is required (e-g., when decipols are being assessed; see below). Subjects may be selected as to their adherence to performance criteria but should belong to an assumed target population.

Assessment of decipol levels. An example of magnitude estimation using several references is assessing decipol levels with a trained panel. In this method, a panel of subjects is selected and trained to evaluate the perceived air quality in decipol, with the use of a reference gas, acetone (2-propanone), supplied by an olfactometer (decipolmeter)[153].

Magnitude estimation of odour intensity. Magnitude estimation with several references (1-butanol) has been used to measure perceived odour intensity of flooring materials[154,155,156]. Subjects were selected and trained to assess unknown butanol samples against the 8 reference concentrations scale increasing in a geometric manner[157]. Flooring material samples were either placed in large environmental chambers where panel members successively evaluate the perceived odour intensity of the samples[156] or introduced in small individual bags supplied to each panel member[155].

d) Master scaling

Master scaling is based on free number magnitude estimation with several references but without moduli. The method gives to the subjects a large freedom of responding similar to that in free-number estimation. However, there is no risk of distorted scales and the instructions are clear for the subjects. The master scale is defined by five or more concentrations of a reference chemical that are jointly scaled with the target air samples during the whole investigation. The whole set of sensory data is transformed with factors necessary for transforming the individual psychophysical functions of these references to the group function for the references.

An advanced equipment (olfactometer) is required. The panel can be small- to mediumsized. No training is allowed. There are few requirements on the test subjects but the panel must belong to the target population. Individual scale calibration is possible by transforming to the scale of reference stimuli. Master scaling produces data on ratio scales.

The usefulness of the master scaling is that the objects of investigation can be compared in absolute terms by their position on the same master scale. Further advantages are that one can compare present results with earlier studies and it is not necessary to know the target stimuli in physical units (like in mixtures of emissions from building materials).

The use of master scaling will:

- serve as an indicator of the subject's scaling behaviour, e.g., panel performance,

- be used for calibrating perceptual scales,
- make standardisation possible by the aid of the psychophysical function of the master,
- control for the range effect of perceptual scales.

6.7.3.3. For the judgment of unpleasantness

Value judgement can be based upon perceived intensity and/or perceived quality of the sensory stimulation. The result can range from hedonic tone to acceptability.

a) Classification (yes/no)

Methods of classification of IAQ are based on a less well established theory. The typical example is counting persons reporting on a binary yes-no response task (for checking whether the perceived air of the sample is deemed unpleasant by a majority of the panel members, or not). There are few requirements on equipment, the procedure is fast, it can be used by small or large panels and typically no training of subjects is required. However, the subjects must be selected as to representativeness. No calibration is possible and is typically postulated. The results are on nominal scales and, therefore, it does not make sense to add, subtract, multiply or divide such values.

Classification is widely used in surveys and in earlier panel studies of IAQ. The most recognised document describing classification of IAQ is probably ASHRAE 62-1989 (1996) which is now under revision. In the proposed revised version it states: "Among a panel of 20 untrained impartial persons more than 80% should find the air acceptable." However, there are limitations in using crude frequency measures, such as counting persons. This method is easy to describe but little attention is paid to response criteria, precision and efficient use of subjects.

Features/methods	Method of Limit	Method of const. Stimul.	Signal detection	Equal attribute matching	Category scaling	Magnitude estimation				Descriptor profiling	Classification yes/no
						Memory reference	One reference	Several references	"Master scaling"		
						the concept of magnitude estimation is well established					
Theory	well established	well established	very well established	less well established but similarity empirically verified	not well established but postulated; empirically shown to work at times	risk of high variances; empirically shown to work	risk of systematic bias depending on location of standard	well established for specific applications but not empirically verified for IAQ measurements	no additional theory but empirically shown to work	less well IAQ established in the context of	less well established in the context of IAQ
Equipment	advanced equipment is required (olfactometer)	advanced equipment is required (olfactometer)	advanced equipment is required (olfactometer)	some cross-modal matchings require little, e.g. visual analog scales; advanced equipm. in intra-modal matching	few requirements	few requirements in testing but semi-advanced equipment required for training	few requirements	semi-advanced equipment is required	advanced equipment required	few requirements	few requirements
Subjects	small-medium panel size. No training required, selection as to sensitivity	small-medium panel size. No training required, selection as to sensitivity	medium-large panel size. Non training required	small-medium panel size. No training required, selection as to adherence to performance criteria, should belong to assumed target population	small-large panel size. No training required. Selection as to representativeness	small-medium size panel. Training required. Selection as to adherence to performance criteria; should belong to assumed target populations	small-large panel size. No training required	small-medium panel. Sometimes training to anchors required, e.g. decipol method. Selection as to performance criteria. Should belong to assumed target population	small-medium size panel. No training is allowed. Few requirements but panel must belong to target population	small-large panel size. Typically no training. Selection as to representativeness	small-large panel size. Typically no training. Selection as to representativeness
Existing for application to IAQ	For single compounds & a few building investigations	for single compounds only	for single compounds only	visual analog scales in wide use. Few other sutides done	in wide use	in some use earlier but not now	not common	in wide use in chamber studies	in limited use	widely used in surveys & chamber studies. Few on odours	widely used in surveys & in earlier sensory studies
Calibration	postulated. Both instrumental & interlaboratory comparisons have been made	postulated. Both instrumental & inter-laboratory comparisons have been made	none	postulated. No inter-laboratory comparison made	typically postulated. In a few investigations calibrated after Thrustonian scaling	some response calibration have been made	some response calibration have been made	in some cases postulated through training. For ratio estimation no calibration; possible to reference physiscal scale	individual scale calibration possible by transforming to scale of reference stimuli	no calibration	typically postulated
level of measurement	nominal	nominal	interval (d')	interval-ratio	ordinal-interval	interval-ratio	interval-ratio	interval-ratio	ratio	Nom. Ordinal interval-ratio	nominal
Recommend. Application	materials testing	materials testing	materials test. IAQ evaluation	materials testing	materials testing IAQ evaluat. Popul. Response	IAQ evaluation	IAQ evaluation Popul. Response	materials testing IAQ evaluat. Popul. Response	materials testing IAQ evaluat.	IAQ evaluation Popul. Response	materials testing IAQ evaluation Popul. response

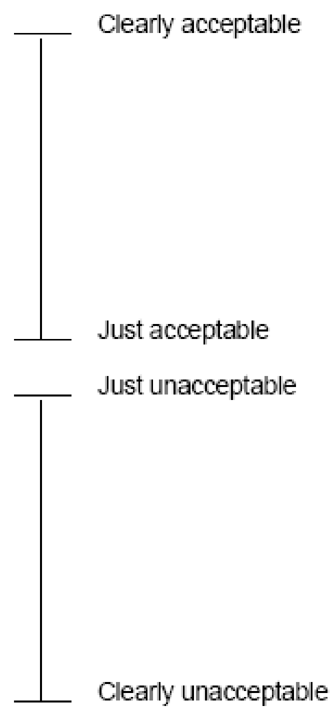
Table 17: Characteristics of the methods recommended by ECA 20.

Appendix 1: Continuous scale slightly modified from Gunnarsen and Fanger (1992).

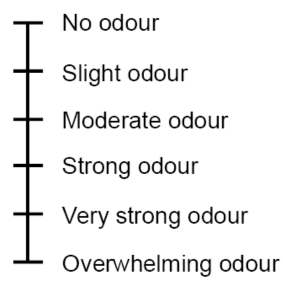
Imagine that you during your daily work would be exposed to the air from the test chamber?

How acceptable is the air quality?

Please mark on the scale and notice the distinction between acceptable and unacceptable:



Appendix 2: Intensity scale



7. Test methods/standards/analysis methods for microbial resistance

7.1. Introduction

Biodeterioration of a various kinds is a major cause of building decay. Biological deterioration is damage caused by living organisms such as insects, bacteria, algae, fungi and mold.
Biological deterioration can occur on every part of the building, inside and outside whenever the environmental conditions are fulfilled to support microbial growth.
In order to discuss the biological deterioration that can affect the indoor climate and the health of those who use or live in the building, only the growth of bacteria and fungi/mold will be considered on finishing and construction materials used on the inner side of the building construction.
Different standards/methods to asses the resistance to fungal growth have been developed by different industries in order to evaluate their products (plastic industry, electronic industry, paints and varnishes, etc) but standards for all building materials are not available.

When measuring a presence of fungi growth on materials taken from an indoor environment, the viable fungi (as colony forming units - CFU) are measured. The laboratory media will always favour certain genera and species, thus several media will be needed for covering the majority of the building associated fungi.
Four investigating moulds associated to health problems, air measurements would provide the best exposure data. However, as the causal agent has not been identified, it has not been established what should actually be measured.
Four main techniques are used for air measurements:
- Cultivation of the viable spores
- Collecting spores and counting them under microscope
- Detecting chemical markers (ergosterol, …)
- Using different molecular-biological techniques (DNA)

Air samplings are generally preferred over sedimentation plates.

In order to asses the susceptibility of a material to fungal growth several test specimens of the same material are inoculated with different fungal spores, and are placed in an environmental chamber presenting ideal conditions for fungal growth.
The different standards established for these purposes are either working in static environmental chambers or either are creating dynamic environmental conditions (transient conditions). Which test method has to be used, depends on the final result you are interested in: a comparative fast method to screen materials, or a method that reflects more the real environmental conditions whereto the material will be exposed.

When the susceptibility of materials is tested, new manufactured materials are submitted to the test conditions. Depending on the purpose of the test, the test specimens can be exposed to a prior conditioning, decontamination etc.
There has been a considerable activity in the field of formulating tests to assess the resistance of organic materials to micro-organisms. Finishing materials (such as coatings), wooden furniture, wall paper, plaster boards, etc. are materials known to be exposed to biological deterioration in an indoor environment.

Recent studies propose the measurement of MVOC's in the indoor air to indicate whether a hidden fungal growth may be present in a water damaged building.
MVOC's are produced as a metabolic by-product of bacteria and fungi and are responsible for the characteristic musty odor that can be found in damp or water-damaged buildings.
Before any visible signs of microbial growth appear, MVOC's are detectable and can therefore serve as early indicators of potential bio-contamination problems.
Microbial volatile organic compounds (MVOC's) are complex mixtures of volatile organic compounds (VOC's) including alcohol, ketones, aldehydes, aromatic and chlorinated hydrocarbons, sulfur-based compounds, amines, and terpenes are known to be produced by microbial metabolism.
When growing on materials the micro-organisms can liberate MVOC 's, however these emission patterns appear to be complex and determined by several factors (the composition of the material, the fungal species present, the humidity conditions,…)

To asses the resistance to microbial growth, materials are exposed to fungal (bacterial) growth and the extend of the growth is visually evaluated and assessed by using a rating scale. Fungal growth on materials can be responsible for the lost of properties, a supplementary test of these properties before and after fungal attack can also asses the resistance of the materials to fungal attack.
Until now, the measurement of MVOC's is not used to asses the microbial resistance of materials.

In this section an overview will be given of the available test methods /standards for the determination of the microbial resistance of building and finishing materials.

7.2. Methods for indoor air screening

Four investigating moulds associated to health problems, the experts use air measurements, dust measurements, and measurements on surfaces. Each laboratory has its own sampling protocol, samplers and analysing methodology. Results obtained from indoor air sampling will be compared with outdoor air sampling. The visual observations of the situation indoor and the results of the different measurements will be used to asses the situation.

Table 18 gives the available test methods /standards for the indoor air sampling.

Method/standard	Scope/title
Sampling of indoor air	
ISO/DIS 16000-16	Indoor air - Part 16: Detection and enumeration of moulds - sampling by filtration
ISO/DIS 16000-17	Indoor air - Part 17: Detection and enumeration of moulds -- Culture-based method
ISO/DIS 16000-18	Indoor air - Part 18: Detection and enumeration of moulds - Sampling by impaction

Table 18: Standards for indoor air sampling

7.3. Methods for fungal resistance

Building materials exposed to environmental conditions and /or with poor maintenance can lead to mold growth. Some materials are more likely than others to support microbial growth. As a result these materials become potentional indoor sources of bio-contaminants including mold. Common materials susceptible to mold growth include porous materials and those with cellulose substrates. These may include gypsum wallboard, ceiling tile, insulation, textiles, wall coverings, floor coverings upholstered furniture, and office panels. In some cases materials may be treated with anti-microbial agents as a preventive step. The ability of these materials to support or to resist mold growth is often not well documented.

Testing protocols have been established to determine how susceptible or resistant a product may be to mold growth. Most of these protocols are translated into international standards, designed specifically to screen products. It involves the study of molds most likely to contaminate products. Materials are inoculated with mold and placed in environmental chambers with elevated humidity conditions. These elevated humidity conditions can be either static or dynamic. Mold growth is measured over time, and the results will indicate if a product is likely to support mold growth under these pre-defined environmental conditions.

As the standard test methods are used, the methodology within standardised measurement and analysis provides consistent testing of materials within a product group and across product groups. The methodology is applicable for newly manufactured products before they are used in construction. Products taken from inventory or from within a building can also be studied but these may be soiled or pre-contaminated. Resultant data may not be considered representative for new manufactured products.
The methods are applicable to newly manufactured products and may not serve as a predictor of mold resistance based on long term usage of the product, with exposure to soil and varying environmental conditions.
The methods categorizes new building materials resistance to mold growth, it does not assess the human risk involved with the use of materials as an end user.

Each standard is based on the same test profile:

(1) Selection of suitable specimens for determination of pertinent properties
(2) Inoculation of the specimens with suitable organisms
(3) Exposure of inoculated specimens under conditions favorable to growth
(4) Examination and rating for visual growth
(5) Removal of the specimens and observations or testing either before cleaning or after cleaning and reconditioning

Each standard uses its own mix of fungal spores, humidity conditions, incubation time, moments of evaluation and evaluation scheme, so that comparing data, without knowing the details of the test conditions could be difficult.

In the following table an overview is given of the available methods/standards for determination of the fungal resistance. This list is not exhaustive, but these standards can be used to test different building and finishing materials used indoor.

Microbial resistance of materials		Standards
EN		
EN 1104		Paper and board intended to come into contact with foodstuff- determination of transfer of antimicrobic constituents.
EN 152		Test methods for wood preservatives : Laboratory method for determining the preventive effectiveness of a preservative treatment against blue stan in wood
ENV 807		Wood preservatives Determination of the toxic effectiveness against soft rotting micro-fungi and other soil inhabiting micro-organisms.
DD ENV 807	2001	Wood preservatives. Determination of the preventive efficacity against wood destroying basidomycete fungi
DD ENV 807	1993	Wood preservatives. Determination of the toxic effect against soft rotting micro-fungi and other soil inhibating microorganisms
DD ENV 12038	1996	Durability of wood and wood-based products. Wood based panels. Methods of test for determining the resistance against wood-destroying basidiomycetes
NVN ENV 839	1994	Houtverduurzaamheidsmiddelen Bepaling van de preventieve werking tegen houtaantastende bsidiomyceten
NBN EN 15457	2007	Peintures et vernis- Méthode d’essai en laboratoire permettant de vérifier l’efficacité des agents de conservation du feuil d’un revêtement contre les champignons.
ASTM		
ASTM D 6329-98	2003 (reapproved)	Standard Guide for developing Methodology for Evaluating the Ability of Indoor Materials to support Microbial growth Using Static Environmental Chambers
ASTM C 1338	2000	Standard test method for determining Fungi resistance of insulation Materials and facings
ASTM D 4300	1998	Prüfung des auswirkung von Schimmlepilz auf die Dauerhaftigkeit von Klebstoffvorbereitung und klebfolien
ASTM D 4783	1998	Bestimmung des Widerstandes von Klebstoffen gegenüber bakterien, Hefen und Pilzen
ASTM G 21-96	2002 (reapproved)	Standard practice for determining Resistance of Synthetic Polymeric Materials to Fungi
ASTM G 160	1998	Standard practice for evaluating Microbial susceptibility of Nonmetalic Materials by Laboratory Soil Burial
ASTM D-3273-00		Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an environmental chamber
ASTM D 5590-00		Standard test method for determining the resistance of paint film and related coatings to fungal defacement by accelerated four-week agar plate assay
NF		
NF B 51-295	1980	Panneaux de particules-Méthode d’essais de la résistance à la pourriture (champignons basidomycetes)
XP ENV 12038	1996	Durabilité du bois et des matériaux dérivés du bois- Panneaux à base de bois-Méthode d’essais pour déterminer la résistance aux champignons basidomyces lignivores
NF EN 844-10	1998	Bois ronds et bois scies-Terminologie –Partie 10-termes relatifs à la dis coloration et aux attaques des champignons
NF EN 61300-2-16	1997	Dispositifs d’inter connexion et composants passifs à fibres optiques-méthodes fondamentales d’essais et de mesures partie 2-16 essais moisissures
NF EN 844-10	1998	Bois ronds et bois scies-Terminologie –Partie 10-termes relatifs à la dis

		coloration et aux attaques des champignons
XP ENV 12225	1996	Géotextiles et produits apparentes –Méthode pour la détermination de la résistance microbiologique par un essai d'enterrement
NF X 41-513	1961	Protection des matières plastiques – 1ére partie : méthode d'essais de résistance des constituants aux micro-organismes
NF X 41-515	1962	Protection des matières plastiques ; 3ème partie méthode d'essais de résistance des matériels et appareillages aux microorganismes
NF X 41-517	1969	Protection du papier-Méthodes d'essais des propriétés fongistatiques des papiers et cartons
NF X 41-520	1968	Protection, Méthode d'essais de résistance des peintures aux micro-organismes et de leur pouvoir de protection
NF-X-600		Tests for resistance to micro-organisms of natural or artificial cellulose textiles. Method by mixed inoculation (spores/mycelium)
ISO		
ISO 846	1997	Plastiques- Evaluation de l'action des micro-organismes
EN ISO 846	1997	Plastiques- Evaluation de l'action des micro-organismes
BS		
BS 3900		Part G 6 : Assessment of the resistance to fungal growth
BS 1982-1	1990	Fungal resistane of panel products made of or containing materials of organic origin. Method for determination of resistance to wood-rotting Basidomycetes
BS 1982	1968	Methods of test for fungal resistance of manufactures building materials made of or containing materials of organic origin
BS 6085		Methods for determination of the resistance of textiles to microbiological deterioration
BS 838	1961	Methods of test for toxicity of wood preservatives to fungi
CTM		
CTM 0622		Standard test Method for Determining Antifungal Activity of building Materials Treated with Bound or leaching Antifungal Agents in an Environmental Chamber
CTM 0623		Evaluating antifungal activity of substrates treated with bound or leaching antimicrobial agents
UNI		
UNI 9421	1989	Wood- Determination and criteria of classification of natural durability against fungi basidomyceters- Laboratory method
UNI ENV 12404	1998	Durability of wood and wood based products Assessment of the effectiveness of a masonry fungicide to prevent growth into wood of Dry rot (Serpula Lacrimans) Laboratory method
UNI experimentale 8986	1987	Fabrics and nonovens-Determination of behaviour under the action of fungi and visual evaluation and measurement of change of physical properties

Table 19: Overview of available test methods for the determination of fungal resistance

7.4. Methods for bacterial resistance

Only a few standards describe a methodology to evaluate the resistance of the materials to bacterial growth. Dealing with indoor conditions, and the evaluation of the susceptibility to bacterial growth on building and finishing materials only the ISO 846 describes a clear test methodology to evaluate the resistance to bacteria. This test has been developed to evaluate the resistance to microbial growth for plastics.
The principle of the test is to include the test specimen in an agar layer (incomplete agar) inoculated with a bacterial suspension. The presence of a bacterial growth in the agar, visually observable, indicates a positive test result.

7.5. General trend and important differences between available methods

Many standards are available that deal with the susceptibility of materials to fungal growth. The standards can be divided in two groups:

- Determination of the fungal growth test and
- Determination of a fungi static effect.

The first group of available methods are used to demonstrate the ability of fungi to grow actively on test specimens. Two different principles can be used: standards where test specimens are in contact with an agar medium, and those where test samples are suspended in a climatic chamber, under high humidity conditions ideal for fungal growth (without contact with agar).
In order to evaluate a fungi static effect, materials are placed directly on a fungal culture. The way how the material is inhibiting the fungal growth is assessed and is an indication of the fungi static effect.
In this section the major similarities and the differences between the methods used to evaluate the susceptibility of materials to fungal growth are discussed.

Fungal growth test
These test methods give an idea of the resistance of the material to fungal growth in an environment without another organic source.
The test specimens are exposed to a suspension of different fungal spores in the presence of an incomplete nutrient agar (without a carbon source). Only by attacking the test specimens, fungi can develop themselves. When the fungi are not able to attack the test specimens, no fungal growth will occur.

Fungi static effect

This method is a variant of the growth test in static environmental conditions. The test specimens are exposed to a fungal spore suspension with the presence of a complete nutritive agar (presence of a carbon source). Even if the test specimens do not contain any nutritive substance to support mold growth, the molds can grow on the agar and their metabolites can attack the test specimens. Any inhibition of the mold growth on the test specimen or on the nutritive agar (presence of an inhibition zone) is an indication of the fungi static activity of the test specimen or indicates the presence of a fungicide.

Environmental conditions: In order to accelerate fungal growth on test specimens, they are incubated in an environmental chamber at the ideal environmental growth conditions for fungi. Most of the standards are focussing on mesophilic fungi, so a moderate temperature and high humidity level is requested. The standards can be divided in two groups :

- Static environmental conditions
- Transient environmental conditions

Static environmental conditions:

Specimens are placed in an incubation chamber at high humidity conditions and constant temperature ideal for fungal growth.

The exact temperature and humidity conditions can differ from standard to standard, (mostly RH > 85%; T between 24°C and 30°C). Most standards are using mesophile fungi. The contact of the test specimens with the incomplete nutrient agar gives also a moistening of the specimens.

Transient environmental conditions:

This test method is used to demonstrate the antifungal activity of materials under controlled simulated real-world realistic conditions. This method is used to demonstrate the ability of fungi to grow actively on test substrates free from the test set-up nutrients. Specimens are suspended in a climatic chamber with intermittent condensation conditions. The incubation tank is mostly maintained at 23°C + 2°C, surface condensation is induced for 2h, by heating a water layer on the bottom of the incubation tank, at for 10h the heaters are switched off so that no surface condensation is induced but only high humidity conditions are fulfilled.

To inoculate test specimens placed under transient conditions, a direct or an indirect inoculation mode can be applied.

The way of inoculation of the test specimens can change from standard to standard. Some standards do not inoculate test specimens, but most of the standards do inoculate the test specimens in order to have more reproducible test results. The different standards use a mixed spore suspension of the different fungal species.

Two different principles are used:

- Direct inoculation of fungal spores on the test specimens
- Indirect inoculation of fungal spores on the test specimens

Direct inoculation:

The set-up of many antifungal methods results in substrates that are either covered with liquid or solid nutrients from the test medium or directly inoculated with a high level of fungal spores. The direct inoculation method demands to apply a given volume of the spore suspension on the surface of the test specimens, by

Covering test specimens by an agar layer with the mixed inoculum

or

Applying 1 ml of the mixed spore suspension on the test surface by a pipette

or

Spraying on each side of the test specimen 1 ml of the mixed spore suspension to give a coverage as uniform as possible

Indirect inoculation:

The procedure consists of an environmental chamber designed for indirect fungal inoculation of test samples, where fungal cultures (on agar plates) are placed at the bottom of the environmental chamber, inoculation of the test specimens is done by airborne dispersion of the fungal spores. This environmental chamber method provides an environment for active fungal growth while separating the growth conditions (nutrients, moisture, and surface dynamics) found in the agar medium or spore suspension from the growth conditions represented in/on the test substrate.

Overall concentration of fungal colony forming units can be calculated based on Agar Settle Plates over the specified weeks. This current method controls the amount of fungal inoculum on the samples with a more realistic, real-life delivery of the fungi.

Inoculation of samples is the result of indirect insult from the environment thus more realistic to situations in contaminated building environments or material in storage.

Direct inoculation of spore solutions can result in an unrealistic insult of spore load on a sample, pooling of spore insult, and uneven distribution of spore inoculum, which can result in false negative results. Growth of multiple organisms in one chamber, while realistic to real world conditions, can results in competitive growth conditions, which favor one organism over another.

Well sporulating fungal cultures are used to make the fungal spore suspension to inoculate the test specimens

Each standard has its own cocktail of fungal species used to inoculate the test specimens. Some standards use 2 different fungal species, while other will use up to 9 fungal species. Differences between standards can be explained by the product group they are intended to screen. The fungal species are more or less adapted to the product group like paints and varnishes, plastics, panel products, etc. A lot of standards mention that depending on the materials to screen, the choice of fungal species can be adapted to more representative fungal species.

Number of test specimens: For micobial test methods, a minimum of three test specimens for each material, submitted to the microbial action is recommended. One test specimen is requested as a reference and is kept by normal environmental conditions (normal humidity and room temperature).Some standard require a supplementary test specimen, kept in the same environmental conditions as the specimens submitted to fungal attack, but without any inoculation.

Configuration of the test specimens: Each standard describes the configuration of the test specimens. These can change from standard to standard.

The standard incubation time is four weeks, with a intermitted evaluation after 2 weeks. For screening different materials, some standards propose to continue the incubation time up to 12 weeks or even more to be able to evaluate better the differences between materials.

Some standards demand a pre-conditioning of the test specimens prior to inoculation.

- To simulate a dirty environment, soiling of the test specimens can be advised. A nutrient solution is pulverized on the test specimens prior to inoculation, or test specimens are incubated in a microbial active soil for some weeks.

- Some standards include aging of the test specimens before they are submitted to the fungal resistance test (example: NF X 41-513,514 and 515).

A prior aging of test specimens can be significant of the behavior in time for products who contain a biocide

However, the aging test methods are not well standardized. Well described test methods like the effect of rainfall and Infra red are not significant for finishing materials inside buildings.

The first evaluation method, described in all standards is the visual evaluation of the extend of the fungal growth on the surface of the test specimens. The visual evaluation can be done by naked eye and with a microscope. Each standard has its own rating scale based on the extend of the fungal growth.

Some standards demand supplementary measurements of physical properties, after cleaning the test specimens. However the methodology to use in order to clean the test specimens is not described, and is left to the interpretation of each laboratory.

8. Test protocols & labels

Over the years a wide variety of organisations have developed a large number of labelling systems. This proliferation is due to a lack of harmonised standards for sampling, emission measurement and analytical procedures, the different construction traditions in different countries and the lack of - or differing - regulations for health and environmental protection.
This section of the report presents the most important labelling schemes which exist internationally and contain references to indoor air emissions of building materials.

Product testing programs assign labels or certificates to products based on pass/fail criteria tied to emission limits determined by dynamic chamber testing. Pass/fail emission limit criteria include three types:

1. Low emission limits based on TVOC and a limited number of VOCs (e.g. Green Label, Indoor Advantage, Nordic Swan, Finland Emission Classification,…)
2. Health effect limits based on extensive lists of toxic compounds (e.g. California 01350/CHPS, FloorScore, Indoor Advantage Gold,…)
3. Combination of low emission and health effects limits based on TVOC and individual VOCs with health based limits and product specific emissions (e.g. Greenguard, AgBB, AFSSET protocol,…)

A general overview of labelling schemes is given in Table 20 and Table 21. These tables are an updated compilation of the labelling systems discussed in the ECA report 24 complemented with internationally well known labelling systems (mostly USA/Canada)[6,158].

In the different subsections a schematic more detailed description is given of the different evaluation protocols to allow detailed comparison between the different labelling systems.

The classification systems/product testing programs evaluate the obtained test results in three manners:

1. Limitation of any problematic emission just by restricting the total emissions, the TVOC. If total emissions are low then the probability is low that any individual VOC may cause problems.
2. Limitation of all VOCs with low irritation thresholds and odour threshols. This approach assumes that present indoor pollution may only be caused by irritation and odour, and that most of these can be determined by VOC testing.
3. Limitation of VOC emissions - the so called LCI values - by setting limit values depending on their specific toxicological properties. This approach is becoming more and more popular.

	AgBB	AFSSET
General		
Origin	Germany	France
Source for more information	http://www.umweltbundesamt.de/buildingproducts/agbb.htm	http://www.afsset.fr/index.php?pageid=714&parentid=424
Legal status	basic concept for Germany	voluntary, complement to French technical Agreement
Scheme/label is based on	ECA report 18	ECA report 18
product types covered	meant for all types of construction products relevant to indoor air	several types of construction products
Testing procedures and standards		
sampling and test specimen	based on ISO 16000-11	ISO 16000-11
-chamber operation	ISO 16000-9	ISO 16000-9/-10
-chamber type	ISO 16000-9/-10	ISO 16000-9/-10
-analyses/VOC	similar to ISO 16000-6	ISO 16000-6
-analyses/aldehydes	ISO 16000-3	ISO 16000-3
-first testing	3 days	3 days
-second testing	28 days	28 days
-third testing	N/A	N/A
-odour test	no, but intended later	complementary
Emission evaluation		
-TVOC definition applied	based on ISO 16000-6 but modified	ISO 16000-6
-TVOC	(3rd day) TVOC 10 mg/mm³, (28th day) 1,0 mg/mm³	(3rd day) TVOC 10 mg/mm³, (28th day) 1,0 mg/mm³
-SVOC	(28th day) TSVOC 100 µg/m³	no
-VVOC	no	no
-Aldehydes, additional requirements	DIBT: 120 µg/m³ day 28	formaldehyde 10 µg/m³ after 28 days
-list with target compounds	NIK, updated yearly, and R value	LCI list October 2006 and R value
-restricted emission of unknown or not accessable VOC	100 µg/m³	100 µg/m³
-restriction of other emitted compounds	no	no
-restriction of carcinogenic VOC	C1+C2 3rd day: 10 µg/m³, 28th day: 1 µg/m³	C1+C2 3rd day: 10 µg/m³, 28th day: 1 µg/m³

	M1	ICL
General		
Origin	Finland	Denmark
Source for more information	www.rts.fi	www.indeklima.org
Legal status	voluntary (private), promoted by government	voluntary (private), promoted by government
Scheme/label is based on	N/A	N/A
product types covered	all type of construction products	open to all types of products relevant to indoor air
Testing procedures and standards		
sampling and test specimen	similar to ISO 16000-11	ISO 16000-11
-chamber operation	ISO 16000-9/-10	ISO 16000-9/-10
-chamber type	ISO 16000-9/-10	ISO 16000-9/-10
-analyses/VOC	ISO 16000-6	ISO 16000-6
-analyses/aldehydes	ISO 16000-3 or EN 717-1	ISO 16000-3
-first testing	28 days	3 days
-second testing	N/A	10 days
-third testing	N/A	28 days
-odour test	CLIMPAQ 28 days; acceptance >0	CLIMPAQ, acceptance >0, intensity <2
Emission evaluation		
-TVOC definition applied	ISO 16000-6	no TVOC monitored
-TVOC	TVOC 200 µg/m²h	all VOC after calculation for model room below 0,5 OT and 0,5 IT
-SVOC	no	no
-VVOC	no	no
-Aldehydes, additional requirements	formaldehyde 10 µg/m²h (28 days)	all aldehydes after calculation for model room below 0,5 OT and 0,5 IT
-list with target compounds	no	database with IT and OT (VOCBASE)
-restricted emission of unknown or not accessable VOC	no	no
-restriction of other emitted compounds	ammonia 30 µg/m²h (28 days) and restriction on casein in the products	all compounds below 0,5 OT and 0,5 IT
-restriction of carcinogenic VOC	C1: 5 µg/m²h (28 days)	C1 n.d. (any time)

	LQAI scheme	Natureplus examples: Linoleum + carpets
	General	
Origin	Portugal	Germany
Source for more information	www.markelink.com/directorios/ct2004/lab-qual-ar-int.htm	www.natureplus.org
Legal status	voluntary (association between private organization and public institution)	Voluntary (private), promoted by several retailer chains
Scheme/label is based on	ECA report 18	AgBB
product types covered	several types of products for indoor use	several types of construction products
	Testing procedures and standards	
sampling and test specimen	ISO 16000-11	ISO 16000-11
-chamber operation	ISO 16000-9	ISO 16000-9/ENV 717-1
-chamber type	ISO 16000-9	ISO 16000-9/ENV 717-1
-analyses/VOC	ISO 16000-6	ISO 16000-6
-analyses/aldehydes	special method	ENV 717-1
-first testing	3 days	24h carcinogens
-second testing	28 days	3 or 28 days
-third testing	N/A	28 days (carpets/SVOC)
-odour test	no	dessiccator test <3
	Emission evaluation	
-TVOC definition applied	ECA report 19	ECA report 18
-TVOC	TVOC 5000 µg/m²h (28 days)	TVOC 200 or 300 µg/m³ (28 days)
-SVOC	not included in TVOC; comparison with respective LCI	TSVOC (ISO) 100 µg/m³ (28 days)
-VVOC	comparison with respective LCI	no
-Aldehydes, additional requirements	formaldehyde 10 µg/m³ after 3 or 28 days	formaldehyde 36 µg/m³ after 3 or 28 days
-list with target compounds	list of identified compound with respective LCI as of 1997 and R value	several limits for single VOC and groups of VOC
-restricted emission of unknown or not accessable VOC	sum of identified compounds without respective LCI < 20 µg/m³ after 28 days	no
-restriction of other emitted compounds	no	no
-restriction of carcinogenic VOC	C1+C2 as considered in ECA report 18	CMR(1+2) and national classifications: 1 µg/m³

	Blue Angel, example: RAL UZ 120 floor coverings	Austrian Ecolabel, example: Ö UZ 42 resilient floor coverings
	General	
Origin	Germany	Austria
Source for more information	www.blauerengel.de	www.umweltzeichen.at
Legal status	voluntary (private), promoted by government	voluntary (private), promoted by government
Scheme/label is based on	AgBB	ECA report 18
product types covered	several types of products for indoor use	several types of construction products
	Testing procedures and standards	
sampling and test specimen	based on ISO 16000-11	ISO 16000-11
-chamber operation	ISO 16000-9	ISO 16000-9
-chamber type	ISO 16000-9	ISO 16000-9
-analyses/VOC	similar to ISO 16000-6	ISO 16000-6
-analyses/aldehydes	ISO 16000-3	ISO 16000-6
-first testing	3 days	24h
-second testing	28 days	28 days
-third testing	N/A	N/A
-odour test	no, but intended later	no
	Emission evaluation	
-TVOC definition applied	based on ISO 16000-6 but modified (AgBB)	ECA report 18
-TVOC	(3rd day) TVOC 1200 µg/m³, (28th day) 360 µg/m³	380 µg/m²h (28 days)
-SVOC	(28 th day) TSVOC 40 µg/m³	no
-VVOC	no, but intended later	no
-Aldehydes, additional requirements	(28th day) formaldehyde 60 µg/m³	hexanal 70 µg/m²h, nonanal 20 µg/m²h
-list with target compounds	NIK (agBB), updated yearly, and R value	some limits for single VOC and groups of VOC
-restricted emission of unknown or not accessable VOC	100 µ g/m³	no
-restriction of other emitted compounds	N-nitrosamine	no
-restriction of carcinogenic VOC	C1+C2 3rd day: 10 µg/m³, 28 day; 1 µg/m³	no

	GUT	EMICODE EC1, example: adhesives
	General	
Origin	Germany	Germany
Source for more information	www.gut-ev.de	www.emicode.com
Legal status	voluntary (private)	voluntary (private)
Scheme/label is based on	AgBB	N/A
product types covered	textile floor coverings	products for installation of floor coverings
	Testing procedures and standards	
sampling and test specimen	like DIBt, based on ISO 16000-11	similar to ISO 16000-11
-chamber operation	ISO 16000-9	ISO 16000-9
-chamber type	ISO 16000-9	ISO 16000-9 but minimum 100 litres
-analyses/VOC	ISO 16000-3/-6	similar to ISO 16000-6
-analyses/aldehydes	ISO 16000-3	ISO 16000-3
-first testing	3 days	24h carcinogens
-second testing	N/A	10 days
-third testing	N/A	N/A
-odour test	dessiccator test <3	no
	Emission evaluation	
-TVOC definition applied	ECA report 18	GEV specific, based on IOS 16000-6, sum of TVVOC+TVOC+TSVOC (ca. C5-C22)
-TVOC	TVOC 300 µg/m³ (3 days)	TVOC 500 µg/m3 (10 days)
-SVOC	TSVOC 30 µg/m³ (3 days)	included in TVOC
-VVOC	no	included in TVOC
-Aldehydes, additional requirements	formaldehyde 10 µg/m³ after 3 days	formaldehyde, acetaldehyde each 50 µg/m³ (24h)
-list with target compounds	NIK (AgBB), updated yearly and R value	no
-restricted emission of unknown or not accessable VOC	100 µg/m³	no
-restriction of other emitted compounds	vinyl chloride, vinyl acetate	no
-restriction of carcinogenic VOC	C1+C2 n.d. (3 days)	list of 5 substances (C1 - 2 µg/m³, C2 - 10 µg/m³, C3 - 50 µg/m³)

	Scandinavian Trade Standards
Origin	Sweden
Source for more information	www.www.golvbransch.en.se
Legal status	trade agreement
Scheme/label is based on	N/A
product types covered	several types of construction products
	Testing procedures and standards
sampling and test specimen	specified for each type of product, principally similar to ISO 16000-11
-chamber operation	ISO 16000-10
-chamber type	ISO 16000-10
-analyses/VOC	similar to ISO 16000-6
-analyses/aldehydes	ISO 16000-3
-first testing	28 days after manufacturing
-second testing	26 weeks
-third testing	N/A
-odour test	for self-levelling compounds only
	Emission evaluation
-TVOC definition applied	based on ISO 16000-6 but modified C6-C18
-TVOC	declaration of TVOC at 28 days and at 26 weeks, no limits specified
-SVOC	no
-VVOC	no
-Aldehydes, additional requirements	formaldehyde according to WHO recommendation for self-levelling compounds
-list with target compounds	all > 5 µg/m³
-restricted emission of unknown or not accessable VOC	no
-restriction of other emitted compounds	no
-restriction of carcinogenic VOC	no

Table 20: Labelling schemes for low-emitting materials part I[158]

	Label Name:	Environmental choice EcoLogo			Green Label				Green Label Plus		Green Seal			GreenGuard							
	Agency:	TerraChoice Environmmental Services			Carpet and Rug Institute				Carpet and Rug Institute		Green Seal (non-profit org.)			GreenGuard Environmental Institute (GEI)/Air Quality Sciences (AQS)							
	Countries:	Canada			USA				USA		USA			USA							
	Year Initiated:	1988			1992				2004		1989			~1996							
	Products/Prod. Categories:	~ 3000/120									~ 300/31										
		Unit	Crp Tile	CrpAdh	Unit	Carp	Cush	Adh	Unit	Value	Unit	Value		Unit	Material Specific Values						
contaminants evaluated	2-Ethyl-1-Hexanol							3,00													
	4-Phenyl Cyclohexene				$mg/m^{2}h$	0,05	0,05				$mg/m^{2}h$	0,05		mg/m^{3}	0,0065						
	Aldehydes, Total													ppm	0,1	0,1	0,1		0,1		0,1
	Ammonia																				
	Benzene								mg/m^{3}	0,03				mg/m^{3}				0.0002			
	ButylatedHydroxyToluene				$mg/m^{2}h$		0,30														
	Formaldehyde	$mg/m^{2}h$	0,02	0,02	$mg/m^{2}h$	0,05	0,05	0,05	mg/m^{3}	0,0165	$mg/m^{2}h$	0,05		ppm	0,05	0,05	0,05	0,04	0,05	0,025	0,05
	Ozone													mg/m^{3}				0,08			
	Particles, Respirable													mg/m^{3}			0,05				
	Particles, Total Dust													mg/m^{3}				0,15			
	Styrene				$mg/m^{2}h$	0,40			mg/m^{3}	0,45	$mg/m^{2}h$	0,40		mg/m^{3}	0,07			0,04			0,07
	VOCs, I ndividual													x TLV	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
	VOCs, Total (TVOC)	$mg/m^{2}h$	0,25	0,05	$mg/m^{2}h$	0,50	1,00	10,00			$mg/m^{2}h$	0,50		mg/m^{3}	0,50	0,50	0,50	0,40	0,50	0,25	0,50
	VOCs, (BP 50-250°C)																				
	VOCs, (BP > 250°C)																				
	VOCs, Total (-Water)										g/L	50,00	150,00								
	SVOCs (C 16-22)																				
	Odours																				
	CMT Substances * *																				
Protocol applies to these Material/Furnishings	Adhesives														xxx						
	Appliances															xxx					
	Carpet		xxx			xxx				xxx											
	Carpet adhesive			xxx				xxx													
	Carpet cushion						xxx														
	Ceiling																xxx				
	Consumer products																xxx				
	Flooring														xxx						
	General construction														xxx						
	Insulation																xxx				
	Office equipment																	xxx			
	Office furniture *																			xxx	
	Office workstation																		xxx		
	Paint																				xxx
	Paint-flat											xxx									
	Paint-non flat												xxx								
	Particleboard																				
	Sealants																				
	Textiles														xxx						
	Wall covering														xxx						
	Wood products																				

	Label Name:	Environmentally Preferable Product			Blue Angel		EMI CODE			GuT		Finnish M-1, M-2			Indoor Climate Label		Nordic Swan		
	Agency:	Scientific Certification Systems (SCS)			Fed'l Environ'l Agency/RAL		GEV			Assoc. Envly-Friend Carp.		Bldg Informn Foundn (RTS)			DSIC, NFICL (see below)				
	Countries:	USA			Germany		Germany			Germany		Finland			Denmark, Norway		Scandinavia		
	Year Initiated:				1977		1990					1996			1995		1989		
	Products/Prod. Categories:				~ 3800/80										~ 100 Manuf./9		~ 660/59		
		Unit	Values		Unit	Value	Unit	EC1	EC2	Unit	Value	Unit	M-1	M-2	Unit	Value	Unit	Adh	Value
contaminants evaluated	2-Ethyl-1-Hexanol																		
	4-Phenyl Cyclohexene																		
	Aldehydes, Total																		
	Ammonia											mg/m² hr	0,03	0,06					
	Benzene																		
	ButylatedHydroxyToluene										individual VOCs vs. Published LCI values, or 0.10 mg/m³ if no LCI exists								
	Formaldehyde											mg/m² hr	0,05	0,1250					
	Ozone																		
	Particles, Respirable																		
	Particles, Total Dust															products rated according to time required for levels to drop below thresholds established in VOCBASE			
	Styrene						mg/m³	500,00	1500,00										
	VOCs, I ndividual	x CREL	< 0.5	<0.5						mg/m³	0,10								
	VOCs, Total (TVOC)	mg/m² h	0,50	10,00						mg/m³	0,30	mg/m² hr	0,20	0,50			mg/m²	0,20	
	VOCs, (BP 50-250°C)				mg/m³	0,30													
	VOCs, (BP > 250°C)				mg/m³	0,10													
	VOCs, Total (-Water)																		
	SVOCs (C 16-22)									mg/m³	0,03								
	Odours										desiccator test < 3								
	CMT Substances * *				mg/m³	< 1						mg/m²hr	0,005	0,005					
Protocol applies to these Material/Furnishings	Adhesives			xxx				xxx	xxx									xxx	
	Appliances																		
	Carpet										xxx								
	Carpet adhesive																		
	Carpet cushion																		
	Ceiling																		
	Consumer products																		
	Flooring																		
	General construction		xxx																
	Insulation																		
	Office equipment																		
	Office furniture *																		
	Office workstation																		
	Paint																		
	Paint-flat																		
	Paint-non flat																		
	Particleboard																		
	Sealants			xxx															
	Textiles																		
	Wall covering																		
	Wood products					xxx													

Table 21: Labelling schemes for low-emitting materials part II[6]

All these evaluation and labelling systems - with the exception of AgBB protocol in Germany for flooring materials - are voluntary systems. Important to note is the Directive 2004/42/EC which limits the VOC content for specific paints and varnishes as stipulated in annex II of this Directive (see Table 22)[77].

Product subcategory	Type (A)	Phase I (g/l) (B) (from 1/1/2007)	Phase II (g/l) (B) (from 1/1/2010)
a. Interior matt walls and ceilings (gloss < 25 at 60°)	WB SB	75 400	30 30
b. Interior glossy walls and ceilings (gloss > 25 at 60°)	WB SB	150 400	100 100
c. Exterior walls of mineral substrate	WB SB	75 450	40 430
d. Interior/exterior trim and cladding paints for wood and metal	WB SB	150 400	130 300
e. Interior/exterior trim varnishes and woodstains, including opaque woodstains	WB SB	150 500	130 400
f. Interior and exterior minimal build woodstains	WB SB	150 700	130 700
g. Primers	WB SB	50 450	30 350
h. Binding primers	WB SB	50 750	30 750
i. One-pack performance coatings	WB SB	140 600	140 500
j. Two-pack reactive performance coatings for specific end use such as floors	WB SB	140 550	140 500
k. Multi-coloured coatings	WB SB	150 400	100 100
l. Decorative effect coatings	WB SB	300 500	200 200

(B) g/l ready to use / WB = water based /SB= solvent based

Table 22: Overview of maximum allowed VOC content values for certain paints and varnishes (according to annex II of 2004/42/EC)

As can be derived from Table 20 and Table 21 most of the labeling schemes use similar measurement methods, however the results are often evaluated differently (24h, 3 days, 28 days,…), differences in VOCs measured, limit values and sometimes differences in measurement conditions.

One of the important aspects is the TVOC calculation procedure which differs in labelling schemes using the TVOC concept. In Table 23 the differences in TVOC calculation procedure are highlighted.

Protocol / Standard	TVOC calculation procedure
AFSSET & ISO 16000-6	Sum of all signals between n-hexane and n-hexadecane (C_6-C_{16}), calculated as toluene equivalents
ECA Report N°18/N°19	Sum of all signals (C_6-C_{16}), as many of these as possible calculated with their respective response factors, but non-identified VOC calculated as toluene equivalent
LQAI	according to ECA Report N°19
GEV	Total sum of all signals > 2 µg/m^3 (TVOC (C_6-C_{16}), TSVOC (> C_{16} - ca. C_{22}) plus TVVOC (ca. C_5 - <C_6), all calculated as toluene equivalent
AgBB - TVOC	Sum of all signals > 5 µg/m^3 (> C_6-C_{16}), all VOC with NIK value calculated with their respective response factors, all other VOC as toluene equivalent
AgBB - TSVOC	Sum of all signals > 5 µg/m^3 (> C_{16}-C_{22}), calculated as toluene equivalent
prEN 15052	Sum of all signals between n-hexane and n-hexadecane (C_6-C_{16}), calculated as toluene equivalents

Table 23: TVOC calculation procedure in different labelling schemes (and standards)

An overview of European, American (ASTM) & Asian (JIS) testing standards (mentioned in section 5.1) and testing schedules is given in Table 24[159].

Testing after x days in test chamber	1	2	3	4	7	10	11	12	13	14	28
Basic test: ISO 16000-3/-6			A1 D								A1 D
European testing schedules/standards											
German AgBB/DiBt test			A2 C		Break-off*						A2 C D G
French CESAT/CSTB test (2003)	C		A1								A1 C D G
French AFSSET test (October 2006)			A1 D								A1 C D G
Finnish M1 test											A1 D E F1
EMICODE						A1					
German Natureplus test	B2										A1 B2 C D G
Danish / Norwegian DICL test			A1 D G			A1 D G					A1 D F2 G
German Blue Angel RAL UZ 38	B1										A3 B1 D
German Blue Angel RAL UZ 113		A2 C D									A3 C G
GuT	F3		A4 D G								
Austrian UZ 07 test	B1										A3 B1 D
Austrian UZ 35 test	A4 D F3										
Austrian UZ 42 test											A4
prEN 717-1	D	D	D	D	D	D	D	D	D	D	D
American (ASTM) testing standards											
Californian CHPS section 01350 test							A5 D	A5 D	A5 D	A5 D G	
Hong Kong GL 008-002 test	A5 D	A5 D	A5 D	A5 D							
Asian (JIS) testing standards											
JIS A 1901	A5 D		A5 D		A5 D					A5 D	A5 D
JIS A 1902-1	A5 D		A5 D		A5 D						
JIS A 1902-2	A5 D		A5 D		A5 D						
JIS A 1902-3			A5 D		A5 D						
JIS A 1902-4	A5 D		A5 D		A5 D						

Table 24: European, American & Asian testing standards and testing schedules

Legend Table 24:
Break-off*: The (AgBB) test can be stopped after 7 days after loading the test chamber or test cell if :

- The values determined are below 50% of the 28-day-value
- No significant increase in the concentration of individual substances compared to the measurement on the 3rd day is determined

- A: VOC / SVOC (Tenax / thermal desorption)
- A1: method - ISO 16000-6 or similar
- A2: method DIBt
- A3: method - UZ 38
- A4: method - ECA or similar
- A5: method - ASTM D6330 (2003)
- B: Carcinogenic, mutagenic and teratogenic VOC (Tenax / Thermal Desorption)
- B1: EU categories 1 and 2
- B2: B1 plus additional lists
- C: Carcinogenic VOC (Tenax / thermal desorption)
- D: Aldehydes (DNPH / UV: ISO 16000-3)
- E: Ammonia (Chemosorption / UV)
- F: Odour
- F1: method - M1
- F2: method - DICL
- F3: method - GuT
- G: Special calculation (LCI, NIK, CREL,...)

Almost all standards/testing schedules are working with a test chamber temperature of 23°C in contrast to Japan where testing is done at 28°C (and Korea where testing is done at 25°C).
Relative humidity is set to 50% in most standards/testing schedules with some exceptions. The most important exception is the standard prEN 717-1 used in the wood sector which sets the relative humidity to 45%. The same is true for Austrian UZ 07 and German Blue Angel RAL UZ 38 (floor coverings made of wood).

An overview of the different testing parameters for chamber emission testing is given in Table 25[160].

Testing protocol/label	Air exchange rate (1/h) / product loading factor (m^2/m^3)	T (°C)	RH (%)
EN ISO 16000-9	0.5/0.4 for flooring materials 1.2 for wallcoverings 0.011 for sealants	23	50
CEN/TC 351 standard	0.5/0.4 for flooring materials 1 for wallcoverings 0.05 for small surfaces 0.007 for very small surfaces	23	50
Emicode	0.5/0.4	23	50
Finnish M1	ISO 16000-9	23	50
DICL	Specific for product group	23	50
French CESAT/ CSTB C Classification (2003)	ISO 16000-9	23	50
French AFSSET (2006)	ISO 16000-9	23	50
French AFSSET (2009)	CEN/TC 351 standard	23	50
German AgBB/DIBt	ISO 16000-9	23	50
German Blue Angel RAL UZ 38 (wooden products)	1.0/1.0	23	50
German Blue Angel RAL UZ 113 (adhesives)	1.25	23	50
Austrian UZ 07	1.0/1.0	23	50
Austrian UZ 35	0.5/0.4	23	50
Austrian UZ 42	1.25	23	50
GUT (textile flooring)	0.5/0.4	23	50
Hong Kong Green Label for textile and elastic flooring	0.5/0.4	23	50
Natureplus	ISO 16000-9	23	50
Nordic Swan (adhesives)	1.25	23	50
US Green Label for textile, elastic flooring and adhesives	0.5/0.4	23	50
US Greenguard	1.0/product specific	23	50

Table 25: Overview of testing parameters for chamber emission testing

In the near future (7-8 June 2009) a workshop “Harmonised Framework on indoor material labelling schemes: challenge with a global perspective” will be organised by the European Commission to (try to) reach a consensus on the principles of a harmonised framework on indoor material labelling schemes. This consensus could then lead to the setting up of a larger Forum that will enable the efficient implementation of the harmonised labeling scheme in a wider and integrated context of safe, healthy, energy efficient and sustainable buildings within the EU and outside. The foundations of the harmonisation work already started in 2007 (see annex 4).

8.1. ECA Report N°18

In 1997 the European Collaborative Action "indoor Air Quality & Its Impact on man" published the report "Evaluation of VOC emissions from building products – solid flooring materials"[161]. This report outlines principles for the evaluation of VOC emissions from building materials with respect to their potential effects on health and comfort. Using these principles and available knowledge, an evaluation procedure (see Figure 19) for a special case has been designed, i.e the VOC emission from solid flooring materials. This procedure consists of the following steps:

- Determination of emission factors of individual VOCs and of TVOC (Total Volatile Organic Compounds) using emission test chamber measurements,
- Modelling of indoor relevant VOC and TVOC concentrations using emission factors and simple exposure scenarios,
- Toxicological evaluation of the indoor relevant concentrations. Available air qualityguidelines (AQGs), no observed effect levels (NOELs) and other relevant information are used for the definition of "lowest concentrations of interest" (LCIs) with which the relevant indoor VOC concentrations are compared. The emission of VOC for which no LCI values are available is restricted.

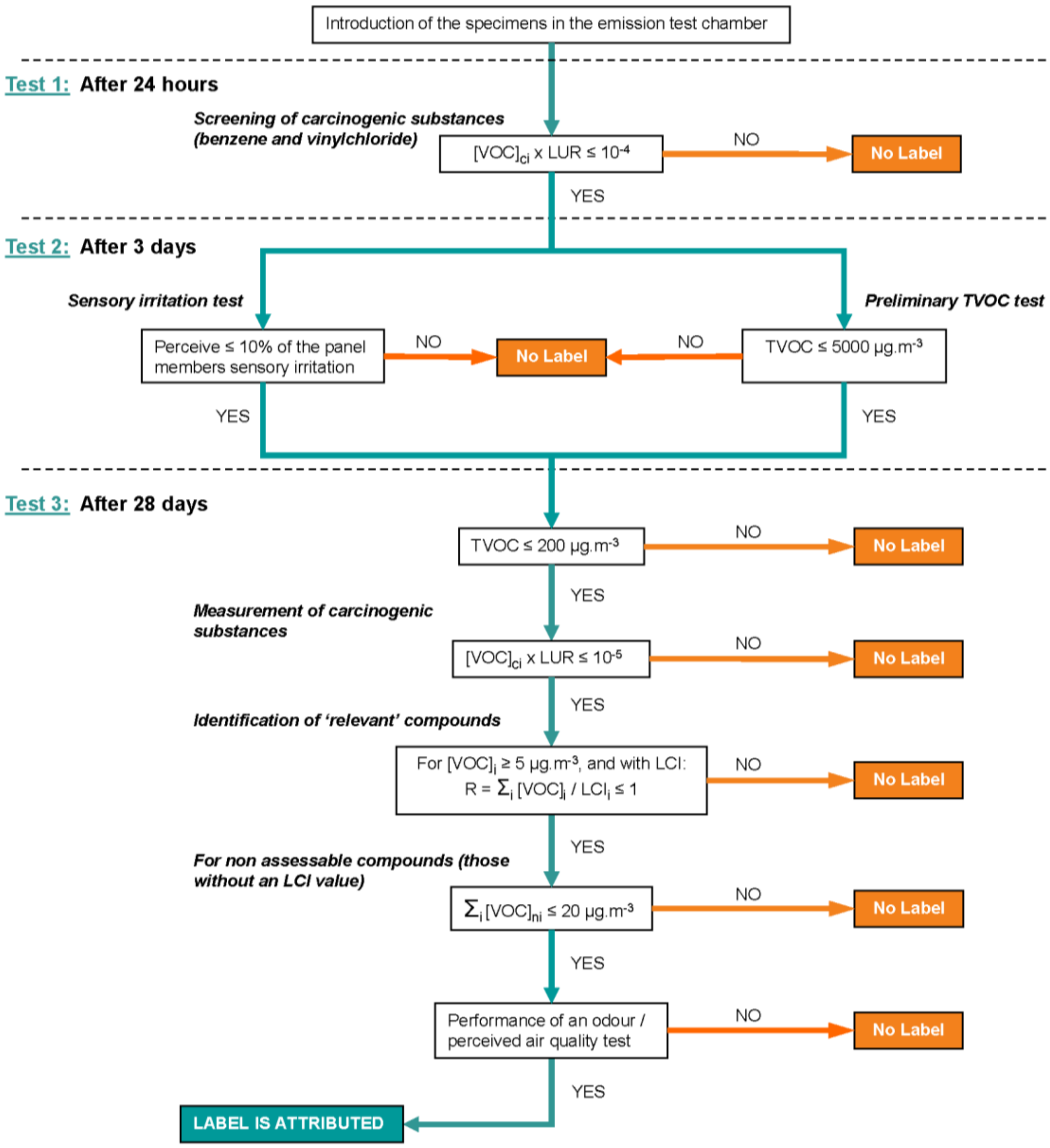


Figure 19: ECA protocol (1997)

Sensory evaluation had been foreseen but no procedure has been given in ECA report no. 18. A review of sensory evaluation methods was given in ECA report no. 20 (ECA 1999).

This protocol formed the basis for many other protocols such as the German AgBB, the French AFSSET scheme, the Portugese LQAI protocol. Many other labels such as Blue Angel, GUT and Natureplus are using modified versions of this approach as basis for their new criteria.

8.2. AgBB protocol (Germany)

In 2000 the Committee for Health-related Evaluation of Building Products, AgBB ("Ausschuss für die gesundheitliche Bewertung von Bauprodukten") presented a procedural scheme for health-related evaluation of VOC emissions from building products used for application indoors[162]. Within this scheme, volatile organic compounds include compounds within the retention range of C_6 to C_{16}, which are considered both as individual substances and in calculating a sum parameter following the TVOC concept (TVOC = Total Volatile Organic Compounds), and semivolatile organic compounds (SVOC) within the retention range from C_{16} up to C_{22}.

The scheme was extensively discussed with representatives of manufacturers and professionals after having been published first in 2000 (AgBB 2000/2001) and at the end of its introductory phase from 2002 to 2004 (Proceedings of the technical dialogues in 2001 and 2004). As a result of these processes, the Deutsches Institut für Bautechnik (DIBt) has incorporated the evaluation scheme into its approval guidelines for the health-related evaluation of building products (DIBt, 2004, 2007, and a revised scheme was presented (AgBB 2005). The latest update of the LCI (NIK) values in the protocol was made in May 2010. Currently discussed or agreed changes of LCI values are given in Table 26.

	Substance	CAS No.	current LCI-value [µg/m³]	under review or discussion
New	**VVOC** e.g.: acetaldehyde, acetone, formic acid, butanal, 2-chlorpropane, ethanol, ethyl acetate, formaldehyde, methanol, pentane			Consideration of VVOC in the AgBB evaluation scheme is under discussion.
New	3-Methoxy-1-butanol	2517-43-3		Application for the determination of a LCI-value has been submitted; Examination of available data
New	N-Ethyl piperidine	766-09-6		Application for the determination of a LCI-value has been submitted; Examination of available data
New	Dimethylisopropanolamine	108-16-7		Application for the determination of a LCI-value has been submitted; Examination of available data
New	Dimethylethanolamine	108-01-0		Application for the determination of a LCI-value has been submitted; Examination of available data
New	1,2-Propylenglykol-mono-n-butylether	5131-66-8		Application for the determination of a LCI-value has been submitted; Examination of available data
New	1,2-Propylenglykol-mono-n-propylether	1569-01-3		Application for the determination of a LCI-value has been submitted; Examination of available data

Table 26: LCI values that are currently under review in AgBB protocol

In contrast to other (voluntary) protocols such as the AFSSET 2006 protocol the AgBB protocol is mandatory for all flooring materials that need authorisation of DIBt under the German Building Construction Regulations. Expansion to other product groups is under preparation.

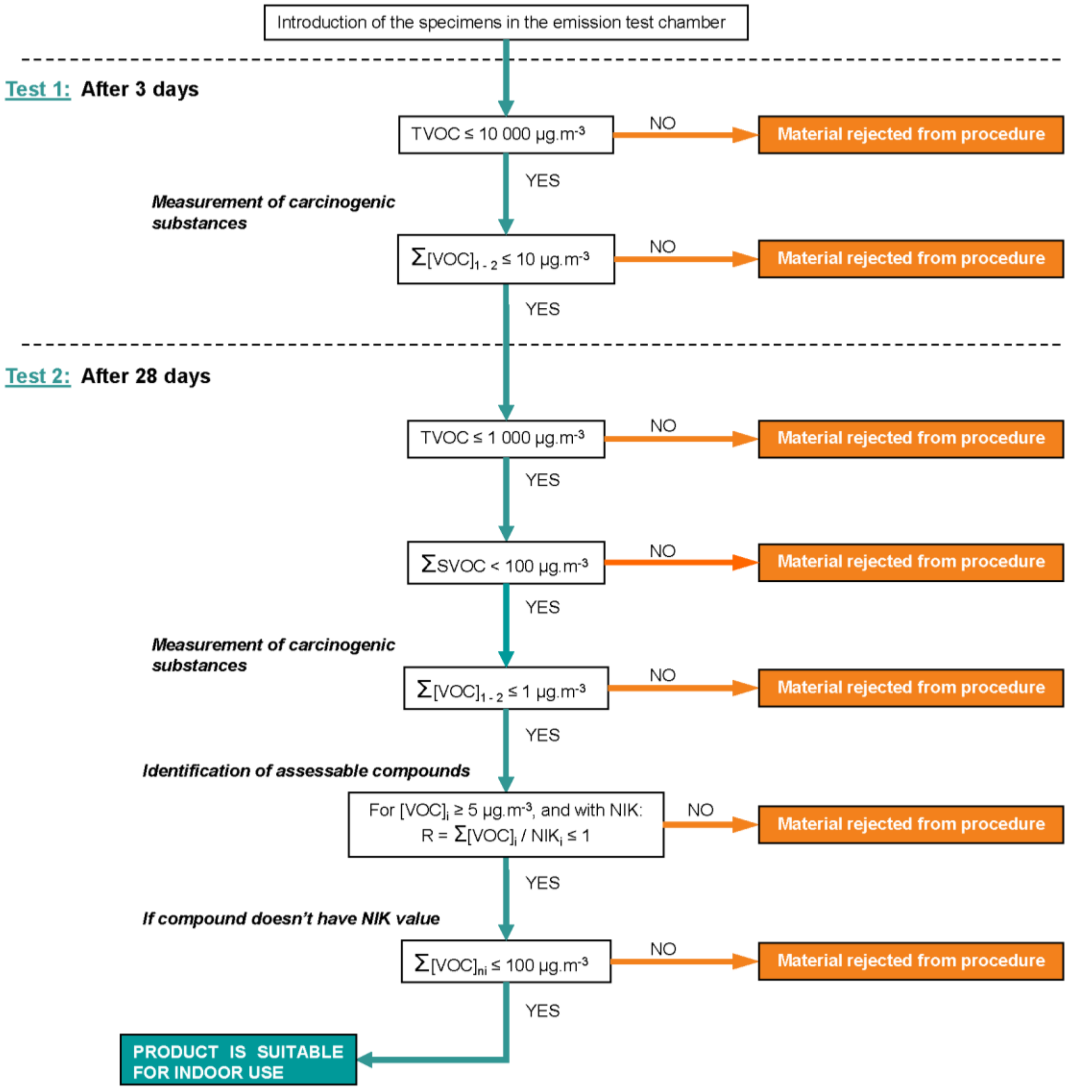


Figure 20: AgBB protocol (2008/2010)

The AgBB/DIBt protocol used for the health assessment of construction products used indoors mentions conditions under which shortening of the measuring period can occur[163]. The break-off criteria are the following:

For all floorings:

The test can be stopped after 7 days after loading the test chamber or the test cell, if the values determined are below 50 % of the 28-day-values and if no significant increase in the concentration of individual substances compared to the measurement on the third day is determined.

It is assumed that a three-day-measurement precedes. The 50 % mark applies to all parameters, consequently, also to the R value.

Amendment: The break-off criteria for the formaldehyde emission of products which is determined in a test chamber/cell according to DIN EN ISO 16000-9 and DIN EN ISO 16000-10 are considered to be met, if the concentration of formaldehyde with a determination by means of

photometry or the DNHP method according to DIN ISO 16000-3 amounts to ≤ 0.05 ppm[164] after 3 and after 7 days.
For "tried and tested" textile floorings:
For "tried and tested" textile floor coverings the approval tests can already be stopped after three days, if the TVOC and SVOC values determined are below 30 % of the 28-day-values and the non-assessable compounds and the R value are below 50 % of the 28-day-values.

8.3. prEN 15052

In 2006 a European (pre)standard was developed in CEN/TC 134 which specified an evaluation procedure for the evaluation of VOC emissions (excluding formaldehyde) from resilient, textile and laminate floor coverings used for applications indoors. The VOC requirements are shown in Table 27.

Characteristic	Requirements
after 3 days	
Any carcinogenic compound as defined in directive 76/769/EEC	not above determination limit: < 2 µg/m³
$TVOC_3$	≤ 10 000 µg/m³
Cut off criteria: If after 3 days all requirements as defined for 28 days are met the test can be terminated as the requirements for 28 days shall be considered to be met.	
after 28 days	
Any carcinogenic compound as defined in directive 76/769/EEC	not above determination limit: < 2 µg/m³
$TVOC_{28}$	≤ 1000 µg/m³
R-value for all assessable compounds	≤ 1

Table 27: VOC requirements defined in prEN 15052
Note: List of carcinogens in 76/769/EEC and 67/548 (used in AgBB) is identical[87,165].

This evaluation scheme - see Figure 21 - is based on the AgBB protocol and is specifically designed for floor coverings. These floor coverings can be supplied in either tile, roll or plank form. Within this scheme, volatile organic compounds include compounds within the retention range of C_6 to C_{16}, which are considered as both individual substances and sum parameter following the TVOC concept (TVOC = Total Volatile Organic Compounds). The main purpose is to protect consumers from exposure to chemical pollutants and resulting adverse health effects (i.e. carcinogens, teratogens, irritants, odours) which could be caused by chemical emissions from materials. This protection can be effectively achieved by supporting the market demand of low emitting flooring materials.
prEN 15052 did not pass the formal vote in 2009 in CEN/TC 134. Industry is considering to publish the document as technical specification.

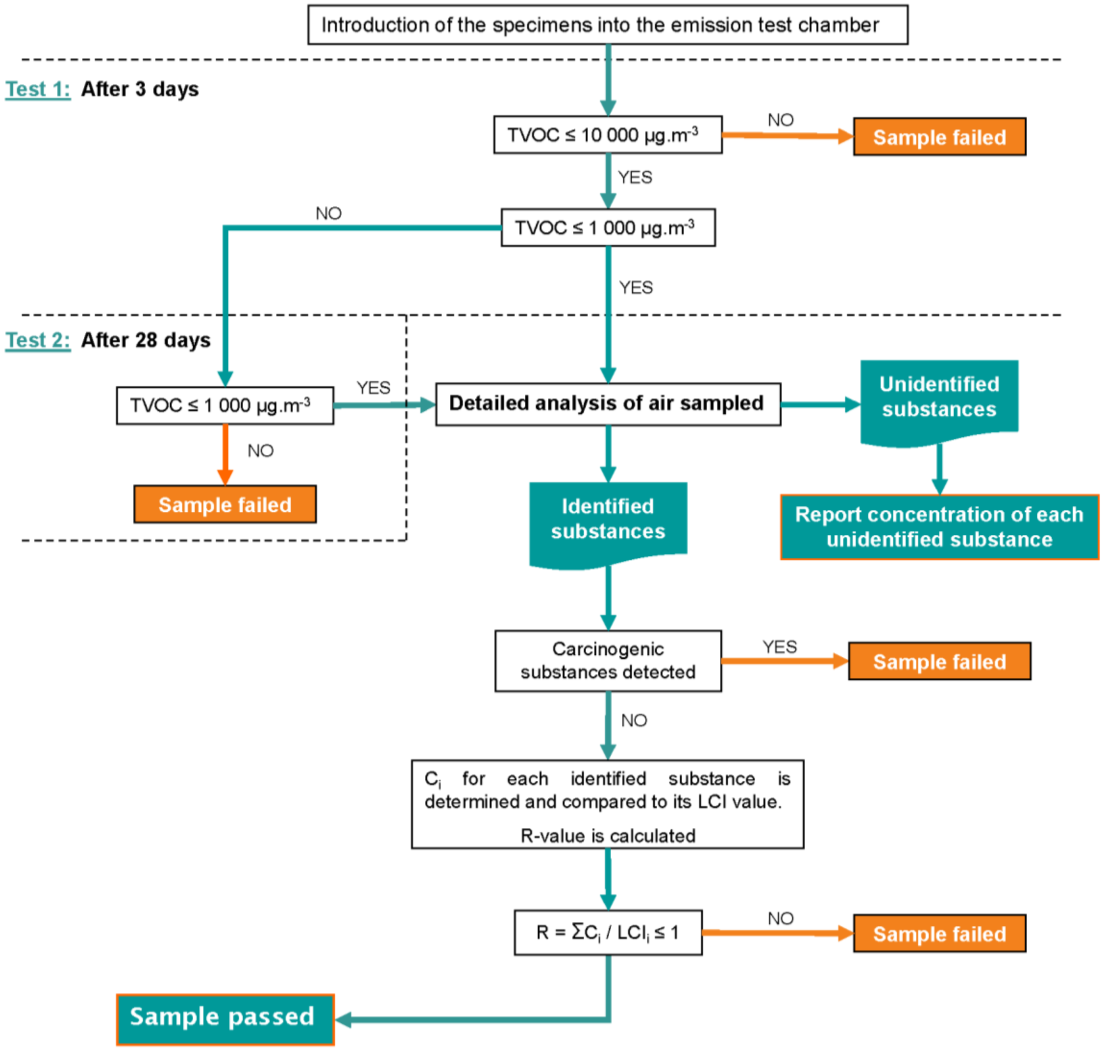


Figure 21: prEN 15052 protocol

8.4. Blue Angel

The Blue Angel was created by the Federal and Länder governments in Germany in 1978[166]. The purpose of its creation was, and still is, to promote products which have considerably better environmental and health characteristics than comparable conventional goods. The Blue Angel is currently borne by nearly 4000 products in more than 100 product categories. The Blue Angel as a voluntary, multiple-criteria-based third party product labeling programme is referred to as "Type I" within the ISO system. Since product comparisons are involved, the EN ISO 14024 standard provides for a transparent procedure. This applies to the selection of product categories, environmental criteria, testing methods etc. Interested parties are involved right from the very beginning, including companies, associations, non government organisations and scientific institutes.

The German Institute for Quality Assurance and Labelling (RAL) in St. Augustin awards the Blue Angel on behalf of the Federal Environmental Agency. Potential applicants first turn to the institute to determine whether an award criteria document already exists for the product in question, or whether criteria need to be established. If basic criteria already exist, the next step merely involves an informal application which is reviewed by the RAL and the Federal Environmental Agency. If the product meets the requirements, a contract is drawn up to cover use of the Blue Angel.

From the very beginning, the criteria for award of the Blue Angel also included health requirements, such as exclusion of substances posing a toxicological risk. 1986 saw the introduction of test chamber measurements, which were used initially for determining formaldehyde emissions from furniture. In the mid-1990s, extensive research work was started whose aim was the comprehensive measurement of emissions of volatile and semivolatile organic compounds and inclusion of emission limitation requirements in the Blue Angel criteria for furniture.

Today, there are several criteria documents for construction products and furniture, which limit emissions of volatile and semi-volatile organic compounds on the basis of test chamber measurements (EN 13419-1) such as[167]:

• RAL-UZ 76 low-emission wood based products like fibreboards, chipboards, wood-core plywood, medium-density fibreboards (MDF) veneer plywood boards, solid wood boards and OSB boards,
• RAL-UZ 102 low-emission wall paints,
• RAL-UZ 113 low-emission floor covering adhesives and other installation materials,
• RAL-UZ 117 low-emission upholstered furniture,
• RAL-UZ 119 mattresses,
• RAL-UZ 120 resilient flooring materials as rubber, linoleum and polyolefin flooring,
• RAL-UZ 123 low-emission sealants for indoor use,
• RAL-UZ 128 low-emission textile floor coverings.

For recent criteria documents for building products and furnishings, the AgBB scheme (see 8.2) was used as assessment basis. While the AgBB scheme assesses construction products with respect to their fitness for use, the Blue Angel is designed to be awarded to products which have a particularly high quality and particularly low emissions. Depending on product group and the material-specific reduction possibilities, emissions of Blue Angel products remain well or very well below the AgBB requirements.

The differences between AgBB protocol and Blue Angel label in the case of floor-covering adhesives are highlighted in Table 28[168].

	Day 3 in the test chamber		Day 28 in the test chamber	
Substances	**Blue Angel**	**AgBB**	**Blue Angel**	**AgBB**
TVOC	≤ 1 mg/m^3	≤ 10 mg/m^3	≤ 0,1 mg/m^3	≤ 1 mg/m^3
TSVOC	N/A	N/A	≤ 0,05 mg/m^3	≤ 0,1 mg/m^3
Carcinogens	≤ 0,01 mg/m^3 sum	≤ 0,01 mg/m^3 sum	≤ 0,001 mg/m^3 per indiv. value	≤ 0,001 mg/m^3 sum
Sum VOC without LCI (NIK)	N/A	N/A	≤ 0,04 mg/m^3	≤ 0,1 mg/m^3
R value	N/A	N/A	≤ 1	≤ 1

Table 28: Differences in requirements between AgBB protocol and Blue Angel for floor-covering adhesives

8.5. Austrian Ecolabel

The Austrian Eco Label was market introduced in 1990 and is awarded by the Federal Ministry of Agriculture, Forestry, Environment and Water Management. It identifies overall environmental preference of a product or service within a specific product/service category and addresses itself primarily to consumers. It is a voluntary label which is promoted by a governmental organisation. The Austrian Consumer Association VKI is responsible for criteria development. The Austrian Eco Label is applicable to different product groups. At the moment criteria documents for 53 product and service groups are published[169]. Emission requirements are part of the following criteria:

- UZ 06 Wooden furniture,
- UZ 07 Timber and derived timber products,
- UZ 35 Textile floor coverings,
- UZ 42 Resilient floor coverings,
- UZ 53 Tapijten

Most of the involved requirements concern TVOC and a small number of VOC related parameters after 28 days in the test chamber. In some cases there are additional requirements on special substances after 24 hours.

8.6. GUT

The GUT ("Gemeinschaft Umweltfreundlicher Teppichboden") label has been created in the early 90's by the European carpet industry[170]. In co-operation with officially recognised test laboratories across Europe, GUT continuously tests products against the highest standards. Furthermore GUT promotes environmentally friendly solutions for carpet installation as well as recycling projects. Compliance with GUT's criteria is achieved by means of GUT's comprehensive product test.
This product test is divided in three sectors[171]:

1 Pollutant test,

This test is done to determine those substances for which either limit values exist or the use is forbidden according to the GUT Test criteria. In general these are substances which cannot be detected or analysed by using the emission chamber method (Heavy metals, flame retardants, pesticides, pyrethroids, TBT etc.).

2 Emission test,

3 Odour test.

The GUT product test is conducted on freshly produced carpets.

• Control tests: Not only new carpets are tested by GUT, but maximum product quality safety is achieved by regular annual control tests at manufacturers' plants and dealers'sales outlets. So called subsequent annual controls are carried out in compliance with specified criteria on no less than 10 % of a manufacturer's certified articles.

• Market controls: In addition to the annual controls on manufacturers' certified articles, GUT carries out regular market controls. Random checks are made at dealers' sales outlets without previous notification.

Textile floor coverings are analysed for emissions of volatile organic compounds and other selected substances in a test chamber examination. For the evaluation of VOC emissions GUT adopted the AgBB scheme in 2004. The emissions are measured after 3 days on freshly produced merchandise according to EN 13419, part 1 and 2. The currently available list of NIK values as published by AgBB is used. Compared to the AgBB scheme lower concentration criteria are used for TVOC and SVOC as shown in Table 29.

The Differences between AgBB protocol (Sept 2005) and actual GUT-scheme are shown in Table 29[172].

conc (µg/m³) after n days	**AgBB** 3	28	**GUT** 3
TVOC	10000	1000	300
VOCs with LCI	x	R ≤ 1	R ≤ 1
VOCs without LCI	x	100	100
SVOC	x	100	30
Carcinogens	≤ 10	≤ 1	not detectable

Table 29: Differences between AgBB and GUT protocol

8.7. EMICODE

In Germany, some manufacturers of flooring installation and allied products/materials decided to develop installation materials with the lowest possible emissions and to promote them in the market. To obtain this, the Gemeinschaft Emissionskontrollierte Verlegewerkstoffe e.V. (GEV), or translated, Association for the Control of Emissions in Products for Flooring Installation, was founded in February 1997.
In order to classify the materials according to their emissions, the GEV developed the EMICODE system[173,174]. There are some basic demands on products labelled with EMICODE:

1. be free of solvents with boiling point below 200 °C;
2. No use of toxic and CMR (carcinogenic, mutagenic or reproduction toxic substances);
3. European Safety Data Sheet must be available;
4. TVOC scale used as classification criterion.

The VOC emission test is carried out by means of environmental test chambers. The chamber air samples are collected on thermal desorption tubes, and analysed by GC-MS. Following test conditions are in use:

- adhesive weight: 300 g/m² approx.
- chamber volume: > 100 liters
- chamber loading: 0.4 m²/m³
- air change rate: 0.5 per hour
- first test sample: after 24 hours, tested for carcinogenics
- second test sample: after 10 days (has changed recently, see below**), tested for VOC emissions

The following 7 cancerogenic substances are checked and have to be below 2 µg/m³ (C1) resp. 10 µg/m³ (C2) resp. 50 µg/m³ (C3) depending on cancerogenic category: benzene (C1), acryloamide (C2), acrylonitrile (C2), 1.4-dioxane (C3), vinylacetate (C3), formaldehyde (C3) and acetaldehyde (C3).
All VOC with more than 2 µg/m³ are summarized to the TVOC value, the first 10 VOC with more than 20 µg/m³ are additionally identified. The TVOC value is the basis for the EMICODE classification. The limit values for the class ranges depend on the type of product group and are defined as follows:

GEV Product Groups	EMICODE emission class		
	EC 1 TVOC in µg/m³	**EC 2** TVOC in µg/m³	**EC 3** TVOC in µg/m³
1. Liquid Products	≤ 100	> 100 ≤ 300	> 300
1.1 Primers			
1.2 Anti-slip coatings for self laying floor coverings			
1.3 Damp proof membranes (coatings and primers			
2. Powder based products with mainly inorganic binder	≤ 200	> 200 ≤ 600	> 600
2.1 Levelling compound based on cement or plaster			
2.2 Tile mortars and joint fillers			
2.3 Waterproofing slurries			
3. Pasty products with high content of organic binder	≤ 500	> 500 ≤ 1500	> 1500
3.1 Adhesives for floor coverings, parquet and ceramic tiles			
3.2 Fixations for floor coverings			
3.3 Waterproofing coatings / sealants			
3.4 Levelling compounds (water based or reactive)			
3.5 Powder based products with high content of organic binder			
4. Ready-to-use products which do not require chemical curing or physical drying	≤ 500 after 1 day	> 500 ≤ 1500 after 1 day	> 1500 after 1 day
4.1 Underlays for flooring installation			
4.2 Sound absorbing underlays			
4.3 Self adhesive tapes and membranes			
5. Joint sealants (water based or reactive)	≤ 300	> 300 ≤ 600	> 600

Table 30: Emicode emission classes

Recently a new testing scheme has been adopted. Emissions are now evaluated after 3 and 28 days[175]. Also a new “very low emission” class has been created the so called Emicode EC1[PLUS]. The new product specifications are shown in Table 31.

µg/m³	After 3 days TVOC	After 28 days TVOC/TSVOC
EC1[PLUS]	750	60/40
EC1	1000	100/50
EC2	3000	300/100

Table 31: New Emicode class specifications

8.8. AFSSET protocol (France)

In 2003 CSTB proposed an evaluation scheme for the assessment of the environmental and health-based properties of building properties[176]. This evaluation scheme was proposed on a voluntary basis in parallel to the French technical approval procedure. The evaluation scheme was based on an environmental product declaration[177] and accepted by the French CESAT which is the horizontal group aimed at tackling environmental and health-related topics related to building products under Technical Agreement.
The health-related criteria examinated by CESAT for the building product in use are summarized in Table 32.

Investigated properties	Classification	
Chemical emissions	C+ C C-	very low chemical emissions low chemical emissions high chemical emissions
Natural radioactive emissions	R+ R R-	very low radioactive emissions low radioactive emissions high radioactive emissions
Aptitude for fungal growth	F+ F F- tot F--	fungistatic product inert product vulnerable product
Aptitude for bacterial growth	B+ B B-	bacteriostatic product inert product vulnerable product
Odour emissions	O+ O O-	odour of very low intensity odour of low intensity odour of strong intensity

Table 32: Former CESAT concept (2003)

The procedure used for the assessment of chemical emissions from building products was based on the protocol described in the ECA N°18 report (1997). On the basis of this protocol CSTB proposed a three level classification of chemical emissions as shown in Table 33.

Technical specifications	Classification of chemical emissions
VOC and formaldehyde emissions fulfil extra criteria (all values divided by 2) of the ECA N°18 protocol	C+: very low chemical emissions
VOC and formaldehyde fulfil all criteria of the ECA N°18 protocol	C: low chemical emissions
VOC and formaldehyde emissions do not fulfil all criteria of the ECA N°18 protocol	C-: high chemical emissions

Table 33: Former CESAT/CSTB classification of VOC emissions according to the ECA N°18 protocol

A three level classification was also introduced for the aptitude for growth of fungi & bacteria and evaluation of natural radioactive emissions as shown in Table 34 and Table 35. The characterization of the ability of building products for growth of fungi and bacteria was done by a method adapted from the standard EN ISO 846 (1997). The characterization of natural radioactive emissions from building products was based on the European Radiation protection 112 protocol[178].

Observations	Classification of the aptitude for fungal growth
No fungal growth on clean specimens No fungal growth on fouled specimens	F+: Fungistatic product
No fungal growth on clean specimens Observed fungal growth on fouled specimens	F: Inert product
Observed fungal growth on clean specimens	F-: Vulnerable product
	Classification of the aptitude for bacterial growth
No bacterial growth on clean specimens No bacterial growth on fould specimens	B+: Bacteriostatic product
No bacterial growth on clean specimens Observed bacterial growth on fouled specimens	B: Inert product
Observed bacterial growth on clean specimens	B-: Vulnerable product

Table 34: Former CESAT/CSTB classification of the aptitude of building products for fungal growth and bacteria

Technical specifications	Classification of natural radioactive emissions
Annual effective excess dose < 0,3 mSv	R+: very low radioactive emissions
0,3 < Annual effective excess dose < 1 mSv	R: low radioactive emissions
Annual effective excess dose > 1 mSv	R-: high radioactive emissions

Table 35: Former CESAT/CSTB classification of the natural radioactive emissions of building products

In 2004 the French Health and Environment Ministries asked AFSSET to prepare a protocol for the evaluation of VOC and formaldehyde emissions from building products. In June 2004 AFSSET established a dedicated working group co-chaired by CSTB which led in 2006 to the AFSSET protocol[79]. The AFFSET protocol is schematically presented in Figure 22.

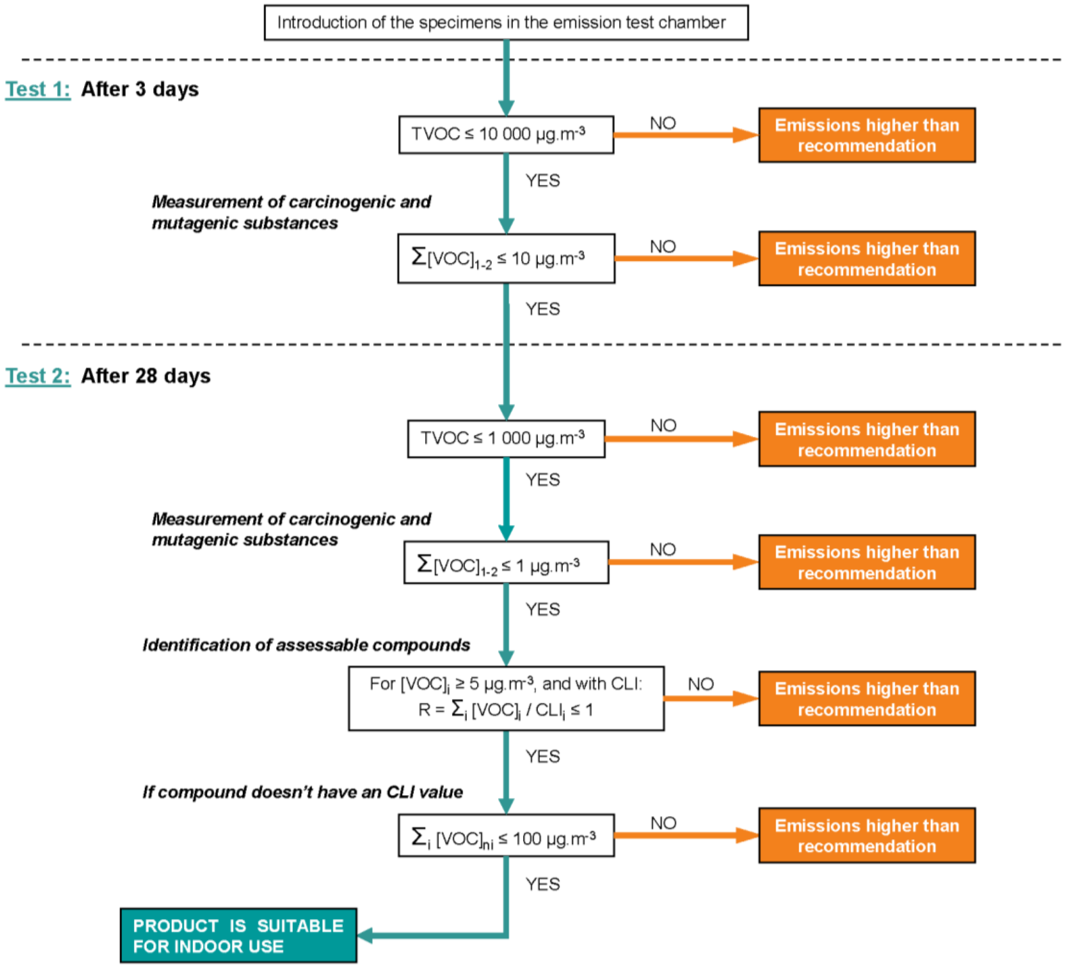


Figure 22: AFSSET (2006) protocol

The differences between the AFSSET protocol and the German AgBB and the original ECA protocol are highlighted in Table 36.

Days	Parameters	ECA Report N°18 (1997)	AgBB (2005)	AFSSET (2006)
1	Carcinogens C1: benzene and vinylchloride	$[VOC]_{ci}$ LUR ≤ 10^{-4}: benzene ≤ 25 ug/m^3 & vinylchloride ≤ 100 µg/m^3	x	x
3	TVOC	5000 ug/m^3	10000 ug/m^3	10000 ug/m^3
3	Σ carcinogens C1 & C2	x	10 ug/m^3	10 ug/m^3 (and M1, M2)
28	TVOC	200 ug/m^3	1000 µg/m^3	1000 µg/m^3
28	ΣSVOC	x	100 µg/m^3	x
28	Carcinogens C1: benzene and vinylchloride	$[VOC]_{ci}$ LUR ≤ 10^{-5}: benzene ≤ 2,5 ug/m^3 & vinylchloride ≤ 10 µg/m^3	x	x
28	Σ carcinogens C1 & C2	x	1 µg/m^3	1 µg/m^3
28	R	$\Sigma[VOC]_i / LCI_i < 1$	$\Sigma[VOC]_i / LCI_i < 1$	$\Sigma[VOC]_i / LCI_i < 1$
28	ΣVOC_{ni}	20 µg/m^3	100 µg/m^3	100 µg/m^3

Table 36: Differences between AFSSET (2006), AgBB and ECA protocol
Note: LUR = lifetime inhalation unit risk / VOC_{ni} = VOC non identified

At first glance the AgBB and the AFSSET protocol use the same evaluation procedure. However four important differences have to be noted, which (may) lead to a different outcome (evaluation) of the same building material in the two protocols:

1. The AgBB and the AFSSET protocol use a different set of LCI values
2. In the AgBB protocol the identified substances with LCI values as well as the carcinogens have to be quantified using their individual calibration factors while in the AFSSET protocol quantification is done on the basis of toluene equivalents.
3. Measurement of formaldehyde in the AFSSET protocol
4. No measurements of SVOC in the AFSSET protocol

In October 2009 the AFSSET protocol was updated to evaluate the VOC and formaldehyde emissions from building and decoration products. The new test protocol is depicted in Figure 23.

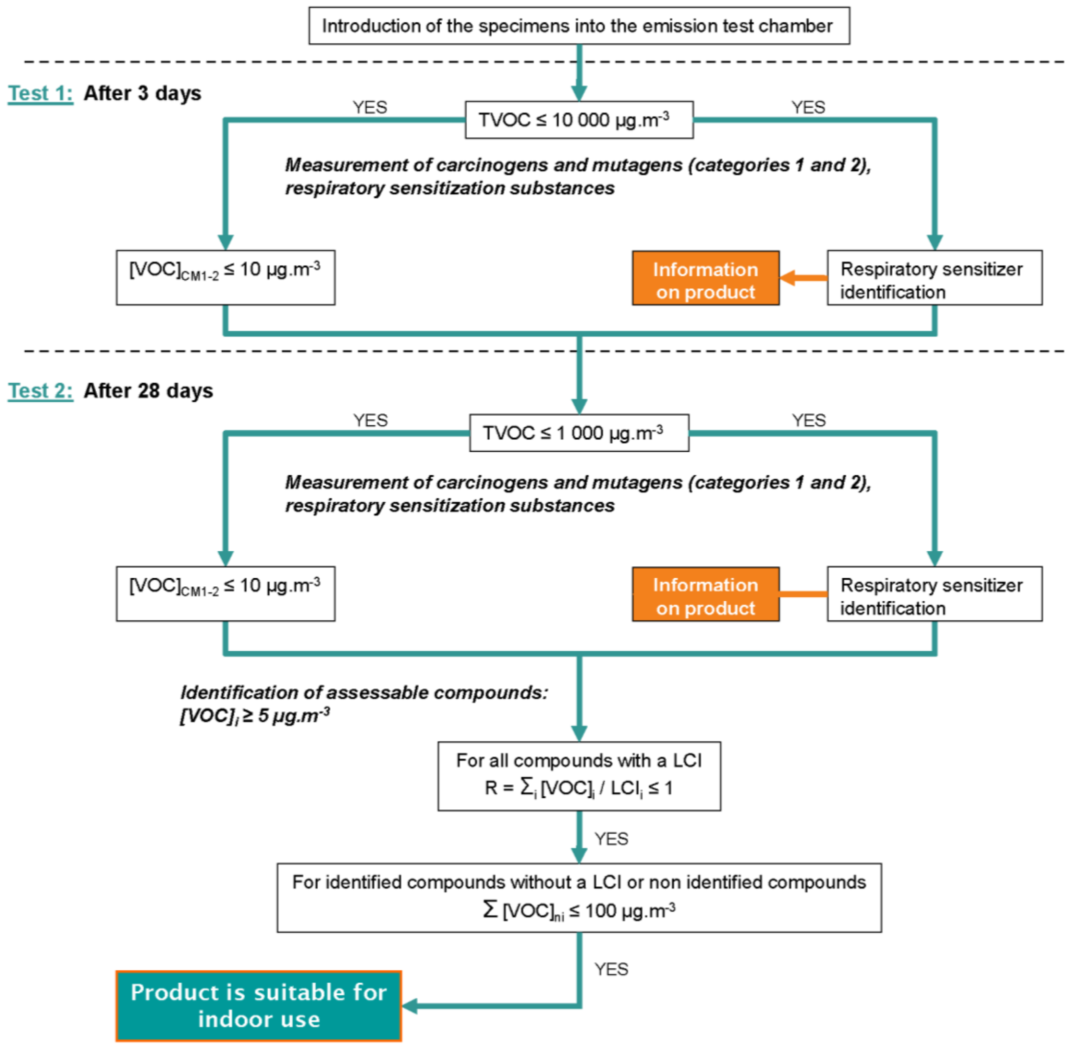


Figure 23: AFSSET (2009) protocol

In August 2009 the French Government adopted the so called "Grenelle I" law. Article 40 of this law deals with indoor air and stipulates:

- → Emissions of building, finishing and furnishing products will be labelled on a mandatory basis
- → CMR compounds category 1 and 2 will be banned in building, finishing and furnishing products
- → Publication of a study on the opportunity to extend mandatory labelling of emissions to other indoor sources

A draft Decree and draft Order relating to the mandatory labelling of construction products with their volatile pollutant emissions have been notified to European Commission (98/34/EC directive) on 23rd December 2009.

8.9. Greenguard label (USA)

The GREENGUARD Environmental Institute (GEI) is an industry-independent, non-profit organization that oversees the GREENGUARD Certification Program[179]. The GEI began certifying indoor products for low chemical emissions in 2001 and has since then established three indoor air standards for indoor products, environments, and buildings.

a. The GREENGUARD Standard for Low Emitting Products classifies goods with low chemical and particle emissions for use indoors, primarily building materials, interior furnishings, furniture, cleaning and maintenance products, electronic equipment, and personal care products.
b. The GREENGUARD Children & Schools Standard is modeled specifically for educational classroom environments and incorporates additional criteria to provide a higher margin of safety for young children. This standard complies with the State of California's Department of Health Services Standard Practice (CA DHS program) (CA Section 01350) for testing chemical emissions from building products used in schools.
c. The GREENGUARD for Building Construction is based on best practices for preventing mold growth in the design, construction, and building operation phase.

All products are tested in dynamic environmental chambers following the GREENGUARD test method, "Method for Measuring Various Chemical Emissions using Dynamic Environmental Chambers". The method follows the guidance of ASTM standards D-5116-06 and D-6670-01 among others.

Chamber air samples are collected for VOCs and aldehydes centered around the elapsed times of 6, 24, 48, 72, 96 (or 120) and 168 hours after initiating the test chamber. The chamber conditions for 168 hour test period are listed in Table 37.

Parameter	Units	Value
Chamber volume	m^3	0.05 - 26
Loading factor	m^2/m^3	0.4 - 1.0
Air change rate	hr^{-1}	1.0 ± 0.05
Temperature	°C	23 ± 1
Relative humidity	RH	50 ± 5

Table 37: Chamber conditions for 168 hour test period

Samples are taken on thermal desorption tubes (Tenax TA) for VOC and TVOC (analysis method TD-GC-MS) and on DNPH cartridges for selected aldehydes (analysis method HPLC-UV).
Table 38 and Table 39 show the allowable limits for respectively GREENGUARD product certification and for GREENGUARD children and schools certification. For more detailed info, visit http://www.greenguard.org/uploads/GGTM.P066.R2_070702.pdf.

	Insulation, wallcoverings, flooring, paints and coatings, general construction materials, adhesives/sealants, ceiling systems, doors, air filters, textiles, visual display products, workstations, casegood systems and moveable walls	OEM materials, surfacing materials, seating, individual casegoods, tables, workstation components
Individual VOCs	≤ 0.1 TLV	≤ 0.1 TLV
Formaldehyde	≤ 0.05 ppm	≤ 0.025 ppm
4-Phenylcyclohexene	≤ 0.0065 mg/m³	≤ 0.0033 mg/m³
Styrene	≤ 0.07 mg/m³	≤ 0.035 mg/m³
Total VOCs	≤ 0.5 mg/m³	≤ 0.25 mg/m³
Total aldehydes	≤ 0.1 ppm	≤ 0.05 ppm
Respirable particles	≤ 0.05 mg/m³	≤ 0.05 mg/m³

Table 38: Allowable limits for GREENGUARD product certification requirements met at 168 hours (7 days) with no preconditioning.

Required for GREENGUARD and CA DHS Program	
Individual VOCs	≤ 0.5 chronic reference exposure limit
Formaldehyde	≤ 13.5 ppb
Required for GREENGUARD only	
Individual VOCs	≤ 0.01 TLV
Total VOCs	≤ 0.22 mg/m³
Total aldehydes	≤ 43 ppb
Total phthalates	≤ 0.01 mg/m³
Total particles (≤ 10 µm)	≤ 0.02 mg/m³

Table 39: Allowable limits for GREENGUARD children and schools certification requirements to be met no sooner than 168 hours (7 days) with no preconditioning.

8.10. LQAI protocol (Portugal)

In Portugal, the LQAI - Laboratory of Indoor Air Quality "Laboratório da Qualidade do Air Interior – is a result of the cooperation between two research centers from University of Porto, under the supervision of professors Eduardo de Oliveira fernandes (IDMEC-FEUP) and Maria Theresa Vasconcelos (ADFCUP – FCUP). LQAI was instituted in 2000.
The LQAI labelling scheme is used to evaluate emissions from flooring materials[180]. After discussion with the manufacturers of building materials it was decide to use the procedure described in the ECA N°18 report with following adaptations:

- The sensory evaluation has not been used
- The carcinogenic compounds are only evaluated after 3 days of exposure, not after 24 hours
- Formaldehyde is always analyzed
- Additional compounds with relevance to the industry are taken into account even if they belong to VVOC or SVOC, and the toxicological evaluation is done by comparing their values with the respective LCIs, as for the other VOCs
- TVOC is calculated according the procedure described in Report N°19 from ECA. Sum of as many VOCs as possible, but at least those contained in a lsit of known VOCs of special interest and those representing the 10 highest peaks, calculated with their respective response factors, but non-identified VOCs calculated as toluene equivalent

The sampling and preparation of the test specimen is done according to EN 13419-3 standard. For the test chamber operation the procedure described in EN 13419-1 is followed. VOCs are sampled and analyzed according to ISO 16000-6 standard and formaldehyde emissions are analyzed using the Modified Pararosaniline method.

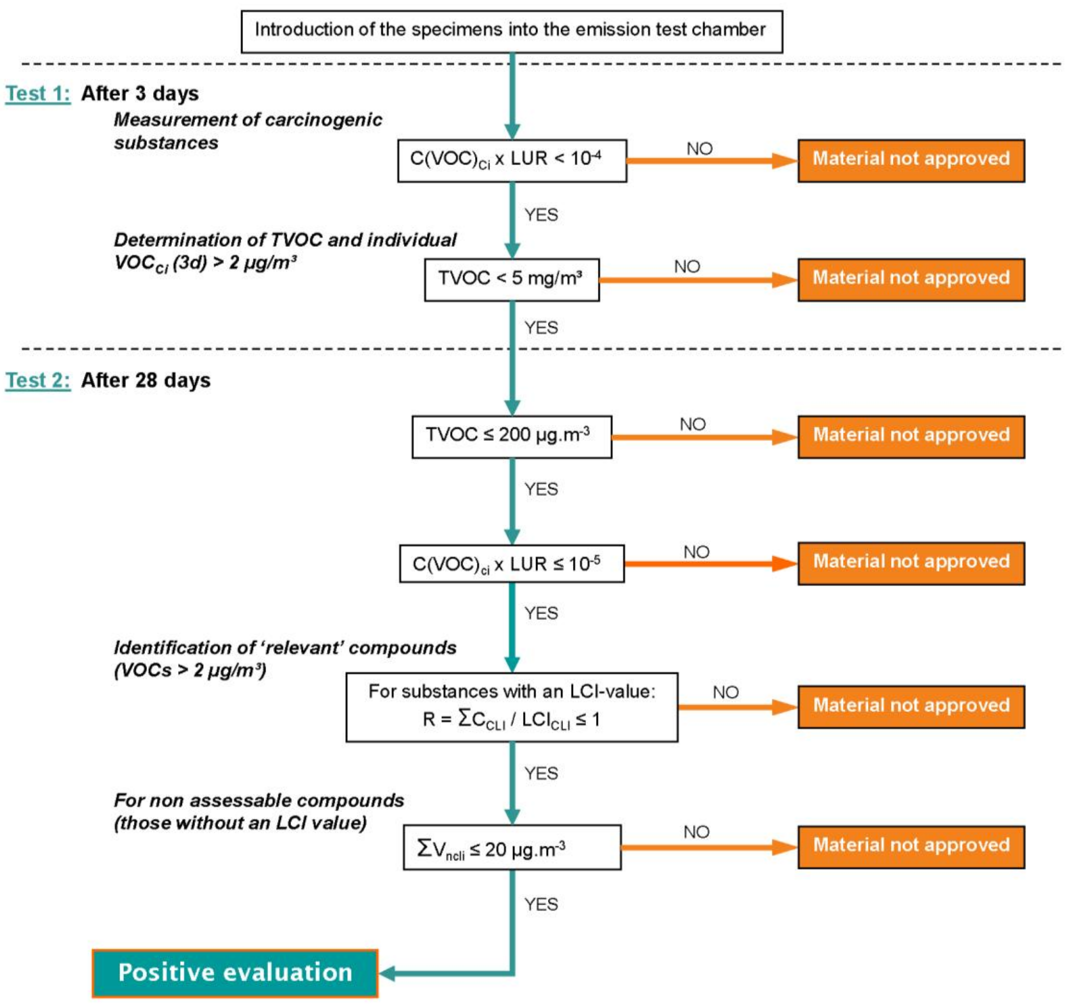


Figure 24: LQAI protocol (for flooring materials)

8.11. M1 (-M2; -M3) – emission classification of building materials (Finland)

This labelling system has three categories with M1 representing low emitting materials[181,182]. Materials are labelled according to the chemical and sensory emissions measured after 4 weeks. The labelling criteria in the different M-classes are shown in Table 40[183].

<table>
<tr><td colspan="2"></td><td>M1</td><td>M2</td></tr>
<tr><td rowspan="4">Chemical evaluation</td><td>TVOC, µg/(m^{2}h)</td><td><200</td><td><400</td></tr>
<tr><td>Formaldehyde, µg/(m^{2}h)</td><td><50</td><td><125</td></tr>
<tr><td>Ammonia, µg/(m^{2}h)</td><td><30</td><td><60</td></tr>
<tr><td>Carcinogens IARC (1987) category 1</td><td colspan="2"><5µg/(m^{2}h)</td></tr>
<tr><td rowspan="2">Sensory evaluation</td><td>Sensory assessment, percent of unsatisfied</td><td><15%
(result ≥ +0,1)</td><td><30%</td></tr>
<tr><td>Odour description</td><td>Not odorous</td><td>Not significantly odorous</td></tr>
</table>

Table 40: Finnish building material labelling system

Emission class M3 includes materials whose emissions exceed the values specified for materials in category M2.

A minimum of 70% of the compounds shall be identified.

Furthermore, plasters and tiling products, levelling agents, putty, mastics, fillers, screeds and renders shall not contain *casein*.

Brick, stone, ceramic tile, glass; metal surfaces and wood hold a special status in the classification.

Comment:

From error calculation and previous experience it is likely that results of the chemical measurements will be reproducible as follows:

- ±10% on the same specimen by the same laboratory
- ±20% across specimens within a laboratory
- ±30% across laboratories.

It has, however, been shown in several inter-laboratory comparisons (ECA 1993/, /ECA 1995/, /Nordtest 1999/, /GEV), that the no homogeneity of the test specimen can cause unexpectedly big variation in the emission test results.

Polar compounds behave unpredictably at the relative humidity defined in the CEN-standards and this testing protocol because of interaction between chamber walls.

The sensory evaluation form of this labelling is shown in Figure 25.

Appendix: The evaluation form for sensory testing of building materials

THE SENSORY TESTING OF BUILDING MATERIALS

Sample: __________

Date: __________

Panelist: __________

Air of test room

☐ acceptable

☐ unacceptable

Imagine that you during your daily work would be exposed to the air from the test chamber!
How acceptable is the air quality? Please mark on the scale on the left hand side.
Fill in the middle column by choosing characteristics which best describe the odour.
After a two-minute pause, assess the air of the test chamber again and mark your evaluation on the scale on the right hand side. We would also appreciate a short comment on the test.
Thank you!

RESULTS

First assessment	Description of odour:	Second assessment
Clearly acceptable	good ☐	Clearly acceptable
	pleasant ☐	
	satisfactory ☐	
	unpleasant ☐	
ACCEPTABLE	disgusting ☐	**ACCEPTABLE**
	woody ☐	
	metallic ☐	
	sweet ☐	
Just acceptable	odourless ☐	Just acceptable
	plastic-like ☐	
Just unacceptable	glue-like ☐	Just unacceptable
	fresh ☐	
	humid ☐	
UNACCEPTABLE	dry ☐	**UNACCEPTABLE**
	heavy ☐	
	stale ☐	
	pungent ☐	
Clearly unacceptable	some other: __________	Clearly unacceptable

Comments: ______________________________

Figure 25: Sensory Evaluation form (M1, Finnish building material labelling system)

New developments of the emission classification of building materials and air-handling components are ongoing in Finland[183].

8.12. Indoor Climate Label (ICL; Denmark, Norway)

The ICL concept was initiated by the Ministry of Housing and Urban Affairs in Denmark in 1993. It is intended as a tool for development and selection of indoor air quality friendly products and better understanding of the impact of products and materials on the indoor air quality in buildings[184].

The main principle of the ICL is the determination of the indoor-relevant time value. The time value is based on chemical analysis of emission of single volatile organic compounds combined with a sensory evaluation of air acceptability and intensity of odour from a newly manufactured product[185].

The chemical analyses are carried out until the emission rate converted to the concentration in a standard room is below half the threshold value for odour and irritation for all individual substances. The threshold values for odour and irritation used are those given in VOCBASE. According to ENV 13419-1 (now replaced by EN ISO 16000-9) minimum 24 and 72 hours and 28 days should as a principal rule be included. In connection with measurements in excess of 28 days and comprising minimum 4 measurement points, modelling can be used[186].

The sensory evaluation is carried out as a control of the chemical measurements. The sensory evaluation criteria for an acceptable air quality is: 1) the air quality shall be perceived as "acceptable" (median of minimum 20 persons' evaluations) using the acceptability scale, and 2) the odour intensity shall be below 2 (moderate odour) using a 6-point continuous scale for odour intensity.

In addition to the chemical analysis and sensory evaluation, ceiling products are also tested for the emission of fibres and particles[187,188].

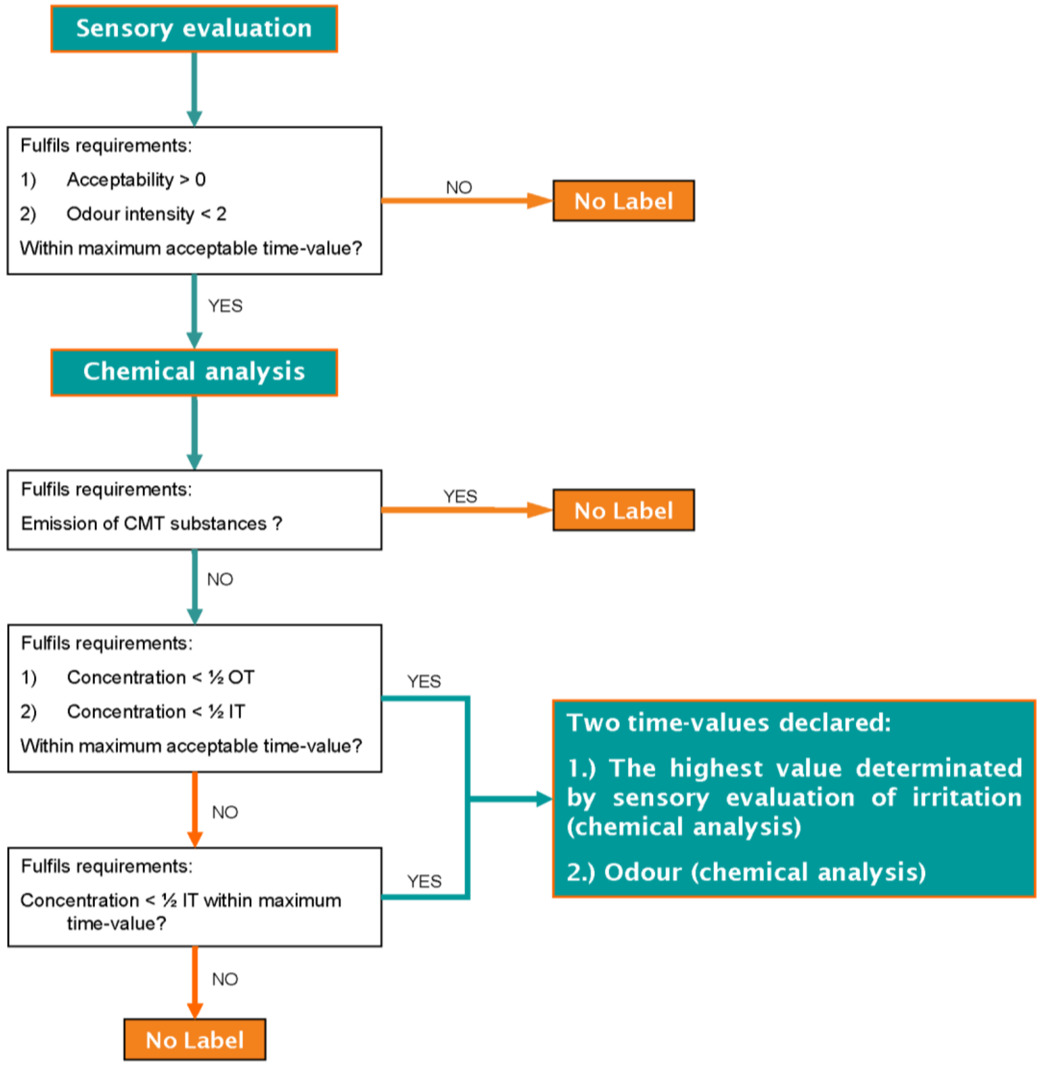
The indoor-relevant time-value is determined as the time (in days) from the product is first released for sale and until the concentration (in a standard room) of all single volatile organic compounds is below half the threshold value for odour and irritation of mucous membranes. At the same time the product must fulfil the requirements for the sensory evaluation of the air quality.

The ICL also requires the product to be accompanied by directions for storage, installation, application, use, cleaning and maintenance etc. to ensure a low impact on the indoor air quality throughout the normal lifetime of the product.

The differences and similarities between ICL and the ECA 18 proposal are highlighted in Table 41.

DICL	ECA-18
Testing after 3, 10 and 28 days	Testing after 1, 10 and 28 days
Individual VOCs are determined	Individual VOCs are determined
No TVOC measurement	TVOC measurement
Threshold for irritation	Use of LCI values
Sensory evaluation	No sensory evaluation method

Table 41: Comparison between DICL and ECA-18 proposal



OT= odour thresholds
IT= irritation thresholds

Figure 26: Declaration of a time-value in the Danish ICL

8.13. Nordic Swan (Scandinavia)

In November 1989, the Nordic Council of Ministers adopted a measure to implement a voluntary, positive ecolabelling scheme in the Nordic countries[189]. The scheme is administered by national boards which co-operate through the Nordic Ecolabelling Board. The board among other things chooses product groups and lay down the final criteria. Secretariats in the participating countries are responsible for implementing the scheme on national level. The Swan logo is used to demonstrate that a product has been evaluated and is considered environmentally sound. The objective of ecolabelling is to provide information to consumers to enable them to select products that are the least harmful to the environment. Ecolabelling is intended to stimulate environmental concern in product development.

In its work on ecolabelling Nordic Ecolabelling follows the ISO 14024 standard: "Environmental labels and declarations - Guiding principles". The product groups and environmental and performance requirements selected by Nordic Ecolabelling reflect the objectives, principles, practices and requirements of the standard. ISO 14024 includes the requirements that criteria should be objective, reasonable and verifiable, that interested parties should be given the opportunity to participate and that account should be taken of their comments.

The criteria are based on evaluation of the environmental impacts during the actual products' life cycle. Based on a thorough examination the criteria set requirements towards a number of factors considered environmentally harmful. Upon application all products found to meet the requirements of the criteria are awarded the environmental label. Due to new knowledge and production methods the criteria must be updated regularly.

Criteria documents dealing with indoor emissions (VOC, formaldehyde) and building materials are available for:

- Floorings
- Adhesives
- Sealants
- Fillers
- Indoor paints and varnishes
- Building panels
- Wood based products
- Small houses

8.14. Scandinavian Trade Standards

In co-operation with different trade associations and in particular the Swedish National Flooring Trade Association voluntary trade standards were developed in 1992 for measurements and the declaration of chemical emissions. In a joint effort between Swedish and Danish researchers the FLEC (field and Laboratory Emission Cell) had been developed. The emission procedure was later on published as a NORDTEST standardised procedure[190].

The procedure requires the material to be tested twice. It was tested first time four weeks after the manufacturing (the estimated time to reach the market) and a second time 6 month after manufacturing. The material is conditioned at 23 ºC and 50 % RH for at least two weeks before the testing. The material needs to be conditioned under the FLEC at least 24 hour before the measurement of emission from the material. When not under test in the FLEC equipment the material is conditioned in 23 ºC and 50% relative humidity (RH) with good ventilation.

The test results were declared as TVOC for comparison between different materials of the same type and also reported as individual compounds to the manufacturer. The results are expressed as concentrations in toluene equivalents. The information of individual components was intended as a tool for improvement of low-emitting material for the manufacturer of the product. The Swedish National Flooring Trade Association developed a form for the declaration of the emission of the various products based on the observed TVOC result and a formula of how to calculate the total emission in a specific application.

The latest trade standard or rather an industrial protocol was developed for the emission characteristics of composite floor structures and for making measurements of the emissions of individual components in a composite floor structure in order to be able to compare their contributions[191]. It enables materials such as concrete, smoothing compound, various types of barrier layers and moisture barriers, adhesives and surface materials to be tested, either individually or in combination, in order to determine their effect on, or contribution to, the overall emission characteristics of the entire floor.

When the behaviour of a single product is to be tested, it is incorporated into a floor structure of which the other components, known as reference products, are well defined. Such a floor structure to be tested is referred to in this document as a 'test specimen'. A 'reference specimen' is also prepared at the same time, consisting of reference concrete, reference adhesive and reference floor-covering. The reference specimen and the test specimen are prepared and handled in as identical manners as possible, and the emissions from them are measured 26 weeks after application of the surface covering.

The cure time as well as the concrete for both the reference and the test specimen has been chosen in order to achieve a constant relative humidity (RH) of 85% under the floor-covering. With reference concrete this will result in the adhesive and the floor-covering being exposed to alcaline hydrolysis resulting in the emission of 1-butanol and 2-ethylhexanol. Extensive test series at SP (Swedish National Testing and Research Institute) indicate that the average sum of emissions of these substances is app. 500 $\mu g/m^2$*h. However, the test results have had a fairly large spread (which has also been the result of other, similar measurements). Thus the emission result from the reference specimen could only be used to confirm the existing aggressiveness of the underlying reference structure.

The reference specimen should reveal a sum of emission of alcohols in the range of 300 to 1200 $\mu g/m^2h$ to be valid.

The result from the test specimen is evaluated from the sum of emitted alcohols, a sum which will be classified as AN 1, AN 2 or AN 3 (classification in reference to alkaline degradation).

Class AN 1: Sum of alcohols < 30 $\mu g/m^2$*h

Class AN 2: Sum of alcohols 30 - 100 $\mu g/m^2$*h

Class AN 3: Sum of alcohols >100 $\mu g/m^2$*h

This protocol consists of three parts with appendixes:

• *Part A, the Reference Specimen,* describes the preparation and emission measurement of the reference specimen, which consists of reference concrete, reference adhesive and a reference floor-covering.

• *Part B, the Test Specimen*, describes the preparation and emission measurement of the test specimen, in which the product of which the characteristics are to be determined is incorporated into the reference system by replacing one of the reference materials (e.g. the adhesive) or by adding it to the standardised reference specimen (e.g. as smoothing compound).

• *Part C, Presentation of results,* describes how to present the results from the emission measurement.

• *Appendixes*, comprises sheets used during the preparation of specimens (appendixes 1a/1b), a sheet for presenting the results from the emission measurements of the test and reference specimens (appendix 2) and, finally, reference adhesive and reference floor-covering declarations of contents (appendixes 3/4).

8.15. EU Eco-label scheme (European flower)

The Flower scheme is part of a broader strategy aimed at promoting sustainable production and consumption [192]. This aim can be achieved in the context of a "framework for an integrated life-cycle oriented product policy", as indicated in the Environmental Action Programme[193].

The EU eco-label provides criteria for several product groups of which indoor paints and varnishes is of importance concerning emissions to indoor air (http://ec.europa.eu/environment/ecolabel/pdf/paints_varnishes/paints_brochure_en.pdf). During the use phase following criteria apply for indoor paints and varnishes:

VOCs (Volatile Organic Compounds):

- Wall paints: < or equal to 30g/L (minus water)
- Other paints: (with a spreading rate > or equal to 15m²/L at hiding power of 98% of opacity): < or equal to 250g/L (minus water)
- All other products: < or equal to 180g/L (minus water)

VAHs (Volatile Aromatic Hydrocarbons):

- Wall paints < or equal to 0.15% of product (m/m)
- All other products < or equal to 0.4% of product (m/m)

Furthermore following criteria apply for the end of life phase of the product:

- The product shall not be classified as very toxic, toxic, dangerous to the environment, carcinogenic, toxic for reproduction or mutagenic in accordance with Directive 1999/45/EC.
- Ingredients shall not contain:
  - Heavy metals (or their compounds): Cd, Pb, Cr VI, Hg, As
  - Alkylphenolethoxylates (APEOS)
  - Diethylene glycol methyl ether
  - Substances (or preparations) classified as very toxic, toxic, carcinogenic, mutagenic, teratogenic, toxic for reproduction
- Limited content of dangerous substances:
  - Active ingredients used as preservatives assigned the risk phrases R23, R24, R25, R26, R27, R28, R39 or R48 (or their combination): < or equal to 0.1% (m/m) of the total paint formulation
  - Ingredients (substances or preparations) assigned risk phrases R50, R51, R52, or R53: < or equal to 2.5% by mass of the product. Total sum of these substances (or preparations): < or equal to 5% by mass of the product
  - Isothiazolinone compounds < or equal to 500ppm
  - Mixture of 5-chloro-2-methyl-2H-isothiazol-3-one and 2-methyl-2H-isothiazol-3-one < or equal to 15ppm
  - Free formaldehyde < or equal to 10mg/kg

Recently (November 2009) the EU ecolabel also contains TVOC criteria for wooden and textile floor coverings.

Volatile organic compounds (VOC)

The finished products must not exceed the following emission values:

Substance	Requirement (after 3 days)
Total organic compounds within the retention range C6 — C16 (TVOC)	0,25 mg/m^3 air
Total organic compounds within the retention range > C16 — C22 (TSVOC)	0,03 mg/m^3 air
Total VOC without LCI (*)	0,05 mg/m^3 air

(*) LCI = lowest concentration of interest; see 'Health risk assessment process for emissions of volatile organic compounds (VOC) from building products' (Federal Environmental Agency).

Figure 27: TVOC criteria for wooden floorings in the EU eco-label scheme

8.16. The Collaborative for high performance schools (CHPS): Section 01350 (California)

Originally, California developed the first building-related environmental specification in early 2000 when a state office building was designed. The goal was to issue a benchmark environmental specification for procuring open office systems furniture. This specification included testing and selection criteria for indoor air quality as well as requirements for recycled contents and lighting, and was entitled "Special Environmental Requirements, Specifications Section 01350". The original version of Section 01350 was rewritten for wide use in other projects such as the Collaborative for High Performance Schools (CHPS) to ensure that building materials protect the health of building occupants. The adapted version of CHPS can be viewed at http://www.calrecycle.ca.gov/greenbuilding/Specs/Section01350/#National_.

Section 01350 contains three key components related to the assessment of building products for their potential IAQ impacts:

1) Screening based upon emission testing of products for their emissions of VOCs with known chronic health effects and reporting of the following data:

- the ten most abundant compounds emitted from the sample
- all compounds on the CA OEHHA CREL list
- all compounds on the CA OEHHA Proposition 65 and ARB Toxic Air Contaminants lists; and

2) Establishment of compliance with the specification by modeling of VOC concentrations for standard classrooms and offices and comparison of modeled concentrations to guidelines based on CRELs.

3) For construction adhesives, it is additionally required that no component listed as a carcinogen or reproductive toxicant on the State of California Environmental Protection Agency lists can make up more than 1% of the total mass of the adhesive.

The original document Section 01350 has been developed and adopted under the auspices of the California Sustainable Building Task Force, a group representing over 40 state agencies and departments. The Task Force has assigned the Department of Health Services' Indoor Air Quality Branch (DHS/IAQ) as the entity in charge of coordinating efforts to revise, update and maintain Section 01350. The details of the 2004 standard practice can be found at http://www.cal-iaq.org/VOC.
In february 2010 this standard practice has been superceded by "Standard method for the testing and evaluation of volatile organic chemical emissions from indoor sources using environmental chambers (version 1.1)".

This practice requires:

- Specific procedures for specimen receiving, handling, and preparation;
- Conditioning of test specimens for 10 days at 23 ± 1 °C and 50 ± 5 % RH, followed by a 96-hr test;
- Sample collection, 24, 48 and 96 hr, following completion of 10-day conditioning period, based on small chamber tests as per ASTM Standard D5116-06;
- Instrument calibration and identification of the following chemicals of concern as listed by Cal-EPA:

    - Chemicals with established Chronic Reference Exposure Levels (CRELs). A CREL is an airborne concentration level that would pose no significant health risk to individuals indefinitely exposed to that level. CRELs are based solely on health considerations and are developed from the best available data in the scientific literature.
    - Chemicals listed as: (a) probable or known human carcinogens, or (b) reproductive toxicants.

- Reporting of the test results: For the 96-h results, list of all target VOCs (individual toxic and abundant VOCs, including formaldehyde and acetaldehyde – see section 4.1 of this standard practice) and TVOC quantified in the chamber with their chamber concentrations and corresponding emission. For the 24-h and 48-h results, list only the formaldehyde and TVOC quantified in the chamber with their chamber concentrations and corresponding emission factors.
- Estimating indoor concentrations of target chemicals based on a standard office space and standard classroom. The parameters to be used for calculation of VOC concentrations in classrooms and office buildings is given in section 4.3 of this standard practice.
- Standardized procedures for reporting laboratory results.

CHPS has recently released the 2009 Edition of its high performance school Criteria[194].

8.17. Green Label and Green Label Plus (USA)

The Carpet and Rug Institute (CRI) is a nonprofit trade association representing the manufacturers of more than 95 percent of all carpet made in the United States, as well as their suppliers and service providers. In 1992, CRI launched its Green Label program to test carpet, cushions and adhesives to help specifiers identify products with very low emissions of VOCs. This label uses the test methodology as described in ASTM D5116-97, the dynamic environmental chamber technology. The CRI works in cooperation with California's Sustainable Building Task Force and the Department of Health Services, Indoor Air Quality Section, as a consequence the carpet industry voluntarily enhanced its Green Label program for carpet and adhesives to meet testing protocols used by CHPS (Section 01350).

CRI has recently launched its next series of improvements called Green Label Plus for carpet and adhesives. This is a revised version of the Green Label program developed to satisfy California's CHPS criteria. This enhanced program sets an even higher standard for IAQ and ensures that customers are purchasing the very lowest emitting products on the market. Green Label Plus expands on CHPS Section 01350 in several respects, including testing annually for the specific chemicals, testing for six additional chemicals, maintaining a chain of custody process and performing an annual audit of the testing laboratory. In order to earn and maintain Green Label Plus certifications, carpet and adhesives must undergo a testing process to monitor continued compliance with the test program requirements.
Every carpet receiving Green Label Plus certification must undergo a 14-day testing process that measures all chemical emissions required by Section 01350, plus six additional chemicals. VOC emissions below the specified threshold for these individual chemicals and the established Total Volatile Organic Compound (TVOC) criteria meet the Green Label Plus criteria. Subsequent annual tests are based on 24-hour testing that measures TVOC's and the individual VOC emissions of thirteen chemicals specific to carpet.

- **Initial test** — The carpet meets the environmental emissions criteria as outlined in DHS/IAQ Section 01350.
- **Quarterly testing** — On a quarterly basis, the carpet meets the established emissions criteria for the total level of volatile organic compounds (TVOCs).
- **Annual testing** — On an annual basis, the carpet meets the TVOC emissions criteria, plus stringent emissions criteria for 13 individual compounds.

	CHPS Section 01350	Green Label	Green Label Plus
Chain of Custody / Sample Validation		X	X
Testing for "Chemicals of Concern"	X	limited	X
Annual Testing		X	X
Annual Testing for "Chemicals of Concern"			X
Quarterly Testing for TVOC		X	X
Tested Against the Most Stringent Criteria			X
Certified Laboratory Required		X	X
Reproducible Protocols		X	X
Annual Audit of Laboratory		X	X
Oversight by Scientific Review Board			X
Bottom line: Assurance specification = delivered		X	X

Table 42: Testing according to CHPS, Green Label and Green Label Plus

More info can be found at http://www.carpet-rug.org/.

8.18. Green Seal (USA)

Assessment programs such as Greenguard, California 01350 and CHPS, Green Label etc deal exclusively with indoor air emissions and provide product labels and certifications.
"Green Product" Assessment programs such as Green Seal deal with a variety of issues such as recycle/reuse, energy efficiency, land use etc. Green Seal also deals with IAQ issues, including consideration of indoor emissions[195].
Green Seal is an independent, non-profit organization that strives to achieve a healthier and cleaner environment by identifying and promoting products and services that cause less toxic pollution and waste, conserve resources and habitats, and minimize global warming and ozone depletion. Indoor air quality is only one of many factors considered by Green Seal.
Green Seal uses two major mechanisms to identify and recommend "green" products:

1) Product Standards and Certification – Green Seal establishes environmental standards that products must meet to achieve certification. The standards/certification process uses life cycle analysis techniques to evaluate environmental impacts. The certification process meets ISO 14024 requirements for "Type I Environmental Labeling." Products are submitted to Green Seal by manufacturers for evaluation against the criteria in applicable Green Seal standards. Based on an analysis by Green Seal using data from testing, the literature, and the manufacturer, products are certified if they meet all Green Seal requirements and are then eligible to use the Green Seal Certification Mark on the product label and in advertising. The certification process includes inspection by Green Seal of the manufacturing facility. The cost of the certification is borne by the manufacturer.

To date, Green Seal has issued 32 environmental certification standards. The following four standards include an IAQ component: Commercial Adhesives (GS-36); Industrial and Institutional Cleaners (GS-37); Industrial and Institutional Floor-Care Products (GS-40); and Paints (GS –11).
The IAQ portion of the standards for these products includes:
- limits on VOC content (per the EPA VOC definition in 40 CFR 51.100(s))
- limits on inhalation toxicity
- prohibitions on carcinogens (per IARC and NTP)
- prohibitions on reproductive toxicants (per California's Prop. 65)
- prohibitions on specified compounds

These limits and prohibitions (except for inhalation toxicity) apply to the product composition not the product emissions; no emissions data or testing are generally required. If test data for inhalation toxicity are not supplied, Green Seal will estimate it using the procedure specified in Appendix A of GS-37.

2) Product Recommendations – As stated in the Green Seal web site,"Recommendations of environmentally preferable products are published as "Choose Green Reports" giving environmental criteria for the category, rationales for them, the product recommendations, and sources for recommended products." Product recommendations are based on life cycle analyses similar to those used in Green Seal's environmental standards and certification process. While product recommendations include consideration of the same factors as environmental standards, no Green Seal certificates are issued. n addition, many of the product recommendation propose the use of non-Green Seal criteria (e.g., CRI criteria for carpet; Greenguard criteria for office furniture). Each Choose Green Report contains lists of recommended products and manufacturers. No manufacturer funds are required for inclusion on the recommended product list.
To date, Green Seal has published 18 Choose Green Reports[196], including the following six that deal with IAQ issues: Carpet; Floor Care Products – Finishes and Strippers; Office Furniture; Office Supplies; Particleboard and Medium-Density Fiberboard, Wood Finishes and Stains. Note that Product Recommendations for materials without Green Seal certifications are being phased out.

8.19. Floorscore (USA)

The Resilient Floor Covering Institute (RFCI) is a trade association of resilient floor covering producers in North America who manufacture tile, sheet vinyl, linoleum or rubber products for residential and commercial flooring installation[197]. The FloorScore program was developed by the Resilient Floor Covering Institute in collaboration with Scientific Certification Systems - SCS (see 8.19). A flooring product bearing the FloorScore label is certified to meet the requirements of California Section 1350.
As a third-party certifier, SCS ensures the program's integrity and independence. SCS (1) works with the manufacturer to identify the appropriate samples for testing; (2) reviewsVOC emission test reports generated by independent testing laboratories for individual candidate products; (3) determines if the test results meet the California Section 1350 requirements for individual VOCs

of concern; and (4) periodically inspects manufacturing plants to review product formulas, processing and quality control in order to define the permitted use of the FloorScore seal.

8.20. Indoor Advantage and Indoor Air Advantage (USA)

Scientific Certification Systems (SCS) is an independent, third-party organization that certifies products which meet recognized standards[198]. For products with indoor emissions, SCS has developed two certification programs: Indoor Advantage and Indoor Advantage Gold[199]. The Indoor Advantage program is a certification for office furniture and seating that meet the requirements of BIFMA M7.1-2006, BIFMA X7.1-2006 and LEED for Commercial Interiors (v. 2.0) EQ 4.5 (see 8.21).

The Indoor Advantage Gold program certifies that building products meet the indoor emissions limits required by the California 01350 program as described in CA Department of Health Services Standard Practice CA/DHS/EHLB/R-174 and the criteria for credits EQ 4.1, 4.2, 4.3 and 4.4 under the LEED-NC (v. 2.2), LEED-CI (v. 2.0), and LEED-CS (v. 2.0) rating systems. Office furniture and seating, in addition to requirements of BIFMA M7.1-2006, BIFMA X7.1-2006 and LEED-CI (v. 2.0) EQ 4.5, meet the requirements of California Section 01350 and the California Indoor Air Quality Specifications for Open Panel Office Furniture.

Indoor Advantage Gold applies to any non flooring product generally used within an enclosed indoor environment such as wall coverings, systems furniture, casework, and insulation." SCS does not perform emission testing, but acts as a facilitator to assist manufacturers in obtaining product certification.

8.21. USGBC- LEED (USA)

The US Green Building Council (USGBC) is a coalition of leaders from across the building industry working to promote buildings that are environmentally responsible, profitable and healthy places to live and work"[200]. The LEED (Leadership in Energy and Environmental Design) Green Building Rating System® is a voluntary, consensus-based national standard for developing high performance, sustainable buildings. LEED standards are currently available for:

- New commercial construction and major renovation projects (LEED-NC)
- Existing building operations (LEED-EB)
- Commercial interiors projects (LEED-CI)
- Core and shell projects (LEED-CS)
- Homes (LEED-H)

LEED standards provide numerical credits for meeting specific requirements leading to a"green building." For indoor air emissions, LEED-NC, LEED-CI and LEED-CS provide credits for the following low-emitting materials:

- Adhesives and sealants
- Paints and coatings
- Carpet systems
- Composite wood and laminate adhesives
- Systems furniture and seating (only in LEED-CI)

In the LEED 2009 version points can be earned for fulfilling environmental quality credits by using low emitting VOC materials. LEED requirements for low-emitting material credits are based on criteria established by other organizations (Green Seal, CRI's Green Label Plus,…).

Note: Also in many other "green building rating systems" such as Japanese CASBEE, French HQE, UK BREEAM, Belgian Valideo, Belgian "referentiekader voor duurzame woningen", etc the possibility exists to earn points by using low (VOC) emitting materials if environmental quality credits are fulfilled[201,202].

8.22. Natureplus (international)

Natureplus was conceived by the "Internationaler Verein für zukunftsfähiges Bauen und Wohnen (International Association for future-oriented building and accommodation)[203]. It promotes the use of those building and accommodation products which incorporate the highest levels of sustainability. Manufacturers can apply to have their products certified with the natureplus®-Quality Seal. In order to do so they must fulfil certain conditions.

Prerequisite for a product to be awarded the Quality Seal is that it complies in full with the Basic Criteria (http://www.natureplus.org/uploads/tx_usernatureplus/RL00Basiskriterien_en.pdf). The award guidelines are subdivide into three hierarchies: the basic criteria (for all products), the award guidelins for product groups and the award guidelines for a specific product.
Among others, functional suitability and composition requirements must be met before the product is exposed to laboratory tests. In general, these tests exist of analyses of ingredient substances and emission tests in test chambers, both according to relevant DIN, ISO and EN standards. The guidelines and corresponding limit values are productgroup-specific.
The different product groups and their guidelines can be found at http://www.natureplus.org/index.php?id=92&L=1

8.23. Indoor Air Comfort (Europe)

Indoor Air Comfort is a pan-European voluntary certification scheme developed by Eurofins for product emissions (building materials and furniture)[204]. The Indoor Air Comfort label shows compliance with emission requirements of all relevant European specifications on two levels:

- The standard level "Indoor Air comfort – certified product" shows compliance of product emissions with the specifications issued by authorities in the EU.
- The higher level "Indoor Air Comfort Gold – certified product" shows compliance of product emissions with the specifications issued by all relevant voluntary labels and related specifications in the EU.

An overview of the limit values used for the Indoor Air Comfort Gold label is shown in Table 43[204].

INDOOR AIR COMFORT GOLD	After 3 days	After 28 days	Unit
TVOC	1000	100	µg/m³
R_D value (based on German NIK values)	-	1	-
R_F value (based on French CLI values)	-	1	-
Sum of VOC without NIK and non identified VOC	-	50	µg/m³
Sum of VOC without CLI and non identified VOC	-	50	µg/m³
TSVOC	-	50	µg/m³
Sum of carcinogens (C1, C2)*	10	-	µg/m³
Any individual carcinogen (C1, C2)*	-	1	µg/m³
4 CMR substances as specified in French regulations, each	-	1	µg/m³
French VOC emission class - TVOC **	-	class A+	-
French VOC emission class - VOCs **	-	class A or better	-
Formaldehyde	-	10	µg/m³
Optional additional tests:			
Ammonia[1]	-	30	µg/m²h
Odour Test $_{M1}$[1]	-	≥ + 0.1	

* If detectable with ISO 16000-3/-6 test methods

** This criterion will be applied only if and since this regulation is in force.

[1] = Only if used for the Finnish M1 classification.

Table 43: Limit values used for the Indoor Air Comfort Gold label

For obtaining the Indoor Air Comfort label following procedure is used[204]:

- Testing of sample in test chamber (testing schedule may differ by product group);
- Reporting of test results (specifications may differ by product group);
- Contract between manufacturer and certification body, including agreements on actions for maintaining low VOC emissions from labelled products, e.g. on details of production, exclusion of certain raw materials, factory production control, quality documentation;
- Initial audit of relevant manufacturing site(s); audit report including the relevant documentation;
- Certification process, including evaluation of test and audit reports, granting or denying of certificate according to the criteria;
- Periodic external audits by Eurofins incl. survey of emission relevant elements of quality documentation;
- Periodic re-testing for ensuring reliability of claims on low emissions;
- Continuous monitoring and improvement of specifications, testing and auditing methodology.

8.24. C2C^SM (cradle to cradle)

For obtaining the Cradle to Cradle^{SM} certification a set of requirements have to be fulfilled[205]. The label is attributed by MBDC (McDonough Braungart Design Chemistry). The certification program includes requirements for:

- Product/material transparency and human/environmental health characteristics of materials
- Product/material reutilization
- Production energy
- Water use at manufacturing facility
- Social fairness/corporate ethics

The Cradle to Cradle^{SM} certification is a four-tiered approach consisting of Basic, Silver, Gold and Platinum levels to reflect continuing improvement along the cradle-to-cradle trajectory. For obtaining the Gold and Platinum level compliance with emission standards have to be demonstrated. Emission criteria are defined as follows (version 2.1.1, revision September 2008):

- TVOC < 0.5 mg/m^3
- Individual VOCs < 0.01 TLV or MAK values (whichever is lower)
- No detectable VOCs that are considered known or suspected carcinogens, endocrine disruptors, mutagens, reproductive toxins or teragens. Based on the lab chosen to do the work what is considered “non-detect” may vary. For the purpose of this certification, anything below 2 $\mu g/m^3$. However, in the case of formaldehyde, it is virtually impossible to achieve this level as ambient air tends to have concentrations higher than this. Therefore the California 01350 standard hasbeen adopted of one-half the REL of 33 $\mu g/m^3$ or 16,5 $\mu g/m^3$ as the threshold limit.
- Time point: 7 days for TVOCs and IVOCs
- Loading scenaruios: BIFMA M7.1 for office furniture and California Department of Health Services (section 01350) for everything else.
- All testing is done according to ASTM D5116 for small chamber, ASTM D6670 for large chamber and BIFMA M7.1 for office furniture

Note: The VOC emission standards are applicable to indoor products only

8.25. Green Label Scheme (Asia)

The *Hong Kong Green Label Scheme (*HKGLS) is an independent, not-for-profit and voluntary scheme for the certification of environmentally preferable products launched in December 2000 by Green Council (GC). The scheme sets environmental standards and awards "Green Label" to products that are qualified regarding their environment performance. As with all eco-labelling programs, the aim is to encourage manufacturers to supply products with good environmental performance and provide a convenient means for consumers to recognise products that are more environmentally responsible, thus promoting a more sustainable pattern of consumption.

In establishing the standards, HKGLS draws from relevant international standards and is benchmarked with well-developed eco-labels to ensure credibility of the standards. An Advisory Committee, composed of members from the academia, industrial and commercial associations and environmental groups, oversees the policy and operation of the HKGLS.
Product environmental criteria (standards: GL-008-001 → GL-008-001-011) have been established for several product groups of building materials: http://www.greencouncil.org/eng/greenlabel/cert.asp

In 2003, the *China Environmental Labelling Program* was launched by the Environmental Protection Administration Environmental Certification Centre (SEPA). They have developed a set of technical criteria for each product category of the Scheme and each product has to be independently assessed by undertaking. On-site inspection and sample product testing, and the test results will be subjected to review and approval. It has adopted international standards and fulfills the technological requirement of environmental products proclaimed by the National Environmental Protection Bureau. Technical requirements of several products categories for the China Environmental Labelling Program can be found on the website: http://www.greencouncil.org/eng/greenlabel/china2.asp

9. Selection of available emission (and odour) data (on building materials)

In this section a compilation is made from scientific publications, information on project websites and (finished and ongoing) research projects of particular interest in the research domain of the HEMICPD project. The database of studied publications, consulted websites and research projects can be consulted in the list of references of section 13.

9.1. NRC/IRC's material emissions study (Canada)

The National Research Council Canada (NRC/IRC) launched a series of projects called "Consortium of Material Emissions and Indoor Air Quality Modeling (CMEIAQ)" with the overall goal of developing guidelines for indoor material selection and ventilation strategies to meet specific indoor air quality requirements. One of the major outcomes of the project was a Material Emission DataBase and single-zone Indoor Air Quality simulation program (MEDB-IAQ). The database contains specimen details, test conditions, and emission information on 90 "Target" VOCs, "Abundant" VOCs and TVOC (total volatile organic compound) from 69 building materials commonly used in Canada[206]. The materials investigated are summarized in Table 44.

Category	Phase I Materials (49)*	Phase II Materials (20)*
Solid and Engineered Wood Materials	• Oriented Strand Board (3) • Particleboard (3) • Plywood (3) • Solid Wood (Oak, Pine, Maple)	• Medium Density Fiberboard (MDF) • Oriented Strand Board (9 for variability tests and long-term tests)
Installation Materials	• Adhesives (3) • Caulking/Sealants (3)	
Flooring	• Carpet (6)** • Vinyl Flooring (2 Tile; 1 Sheet)** • Underpad (2)**	• Carpet & Carpet/Adhesive/Concrete • Laminate (Lam1), Laminate/Underlay (Lam2) & Laminate/Underlay/OSB (Lam3) • Linoleum (Lin1) & Linoleum/Adhesive/ Plywood (Lin2)
Walls	• Gypsum Panels (3)	• Vinyl-Faced Wall Panel (VWB)
Ceilings	• Acoustical Ceiling Tile (3)**	
Interior Finishing	• Floor Wax (2 oil; 1 water) • Polyurethane (3 oil) • Paint (2 water, 1 oil) • Woodstain (4 oil. 1 rep)	
Furnishings		• Countertop (2: upper laminate surface only, all surfaces)

* The value indicates the number of test specimens.
** One DNPH sample was taken at 24 h for these materials in Phase-I.

Table 44: List of materials tested for MEDB-IAQ

9.2. New research findings on building products: avoiding hazardous substances and odours (Germany)

Results of a project carried out by the Federal Institute for Materials Research and testing (BAM), the Hermann-Rietschel-Institute of the Technical University of Berlin and the Federal Environment Agency (UBA) “Environmental and health Provisions for building products” resulted in the brochure “Bauprodukte: Schadstoffe und Gerüche bestimmen und vermeiden - Ergebnisse aus einem Forschungsproject” which will be discussed here[207,208].

"The objective of the project was to test and extend national and international test methods and to assess building products according to the AgBB scheme."

9.2.1 Sensory testing

Currently, the sensory testing is not required for the assessment of materials due to the uncertainties of these measurements. Methods used to determine odour emissions either lead to poorly reproducible results: "Urgent action was needed to develop an adequate test method to assess odour emissions from building products using a reasonable combination of several available approaches".

A method is tested which enables the integration of sensory tests into current test procedures under the AgBB scheme :

Method

The Hermann Rietschel Institute (HRI) developed a method that provides a proper amount of sample regardless of the size of the emission chamber. Laden air is pumped from the emission chambers into Tedlar bags (300-litres). The bags are thermally treated in order to exhibit lower emission. The filled bags were transported to the laboratory of HRI and the new "**Airprobe 2**" was used (acetone comparative scale tool, Figure 28).

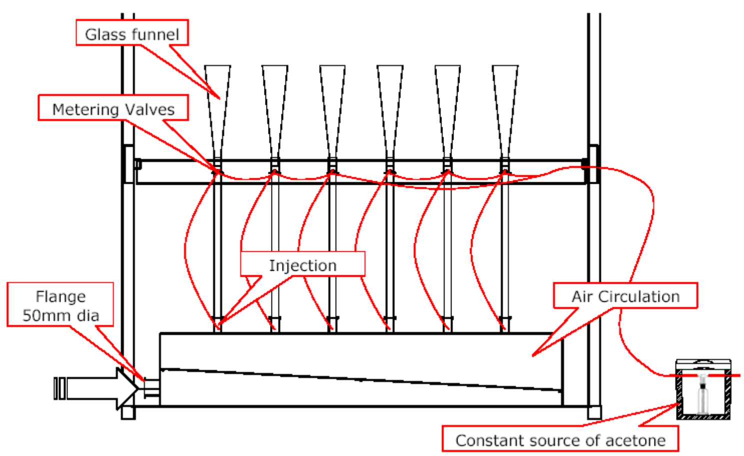


Figure 28: Comparative scale

Perceived intensity (comparative scaled and trained panels) and odour hedonic are determined.
At least eight panellists evaluated the perceived intensity[2] of the sample air. The comparative scale based on 6 different acetone concentrations (0 to 15 pi-300 mg/m^{3}air) enabled the panellists to classify unknown emissions.
Additionally the hedonics is also assessed. For this assessment no comparative scale is used.

The panellists enters the value into a data acquisition software (Figure 29)

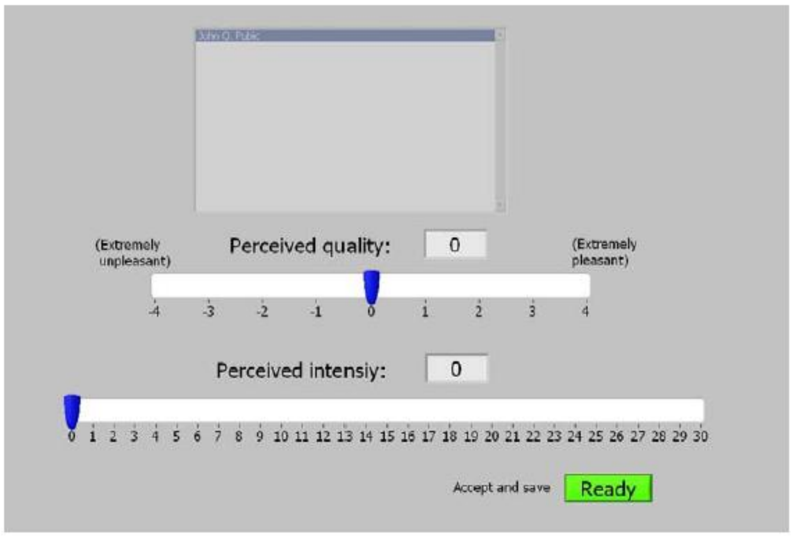


Figure 29: Scales for assessment of the odour samples

Conclusions

The medium standard deviation in the intensity questions is only 24%, while the medium standard deviation is 66% in hedonics assessment.
The results were better than expected. Laboratory environment (the panellists are separated from the buildings material to evaluate), random presentation of neutral air, thermal treatment of the bags has contributed to the good results.

"The results have established the basis for the sensory assessment required by the AgBB sheme. Since the AgBB scheme is an evaluation concept for building products within building law, it can only differentiate between odours to be tolerated and those that should not. The necessary criteria must be developed in further projects. It should also be investigated as to how intensity assessments can be transferred from emission chambers into a real room. For the positive labelling with the Blue Angel for instance, other and more ambitious criteria are necessary".
This method must be further developed and validated for implementation in practice.

[2] Unit of the perceived intensity: pi. 0 pi = 20 mg acetone/m$^3_{air}$ (odour threshold for acetone). The gradation is linear with regard to acetone concentration.

An odour detector (ODP) was installed in parallel to an MS system at the exit a GC. Further investigations are required.

An electronic nose was tested (Kamina nose). The nose was fixed on top the assessment funnel. Classification of the measured values was performed (principal component analysis, linear discriminant analysis. The PCA analysis doesn't give a clear classification of the building materials. Supervises analysis (LDA) give better results. Regression with the intensities assessed by the panelists was not concluding. "The use of sensor systems is feasible for the determination of odour intensity. However, sensitivity and selectivity of sensor systems must be increased in order to be able to distinguish between various building materials more efficiently. Follow-up investigations of combinations of building materials are necessary to facilitate the use of sensor systems in the determination of odour intensity of building materials. The extent at which odour intensity from new and unknown materials can be determined has to be investigated based on a calibration data set from selected materials of different material classes.

9.2.2 VOC testing

In the report emission data after 1,3, 10 and 28 days are available for several building materials:

- 7 acrylic sealants
- 6 silicone sealants
- 6 paste-like synthetic resin plasters
- 13 wood based products (chipboard, OSB board, laminate, cork parquet, etc)
- 4 adhesives
- 5 lacquers
- 6 wall paints
- 1 glass fibre non-woven fabric with adhesive,
- 1 primer on plasterboard
- 1plasterboard (humid surroundings)

9.3. VTT research: Sensory evaluation method of building materials for labelling purposes (Finland)

Principle

To compare the performance characteristics of three test chamber (5 m³, 1 m³ and 100 L) six building materials were tested[115]. Chemical and sensory test results obtained with different chambers were in good agreement. Comparing the result with the Finnish building material classification the chamber size would not have affected the labelling of the materials. Statistical calculations presented here show that for the labelling purposes reliable sensory acceptability evaluations can be performed using a relative small naive, untrained panel.

Test chamber: Climpaq

With Climpaq, when using **diffusor** technique the airflow rate coming out from the diffuser is recommended to be 0.9 l/s (NT Build 482). This is to ensure that even when taking a deep breath the test person only breaths the air coming out from the chamber and the chamber air is not diluted with the surrounding air. This airflow is higher than the airflow rate traditionally used for the emission testing in small-scale test chambers, i.e. chambers smaller than 1-2 m^3, in which the air exchange rates of 0.5 1/h or 1 1/h are used. So the test specimen area required is relatively high compared to the chamber volume.

Test chamber: 5m³

- Why a 5m³ chamber?

A frequently encountered problem is that the tested material is so thick that the required test specimen area in the chamber can not be reached. To overcome the problem a 5-m³ chamber was built. The basic idea was that sensory assessment is made for the same test specimen and under same conditions that were used for the chemical measurements.

- Material for the chamber

Different materials were tested (stainless steel, glass). Electropolished stainless steel was assessed as most acceptable and selected as the chamber material. Sorption characteristics of the materials were not tested.

- Hood technique

The hood is used because with the 5 m³ chamber having air exchange rate of 0.5 1/h the supply air flow rate is 0.7 l/s instead of 0.9 l/s required for the diffusor.

	100 L	1m³	5m³
Loading factor		0.4 m²/m³ for flooring material - 1.4m²/m³ for wall material	0.4 m²/m³ for flooring material - 1.4m²/m³ for wall material
Air exchange rate (h^{-1})	2	0.5	0.5
purpose	Acceptability	Chemical measurements	Acceptability Chemical measurements

Table 45: Test arrangements of the 100L, 1m³ and 5m³ test chambers.

Tested materials

- Linoleum
- PVC
- Pine floor boards, untreated
- Water-based paint on gypsum board
- Parquet, lacquered oak
- Heat-treated pine, floor board

Sensory evaluation

Sensory characteristics were compared between the 5m³ and the 100 L. It was made in according to the instructions given in the Finnish classification of the building materials[182].
This follows the general principles used internationally concerning untrained panels. According to the protocol the *panellist is asked to imagine that he/she in the working environment would be exposed to the air* similar to that coming out of the chamber. This evaluation is made using the acceptability scale -1 (clearly unacceptable)…+1 (clearly acceptable) with +0.1 …

- Panellist

An untrained panel of 7-12 persons already familiar with the test method (personnel of VTT) was used. They evaluated the exhaust air from the two chambers at the same time. Each panellist made two successive assessments from both chambers with a small, 1- to 2- minute breaks between assessments. As the main focus was to compare the 2 chambers the panellist were not asked to evaluate an empty chamber.
The group of voluntary panellists was not the same for all the consecutive assessment sessions. They were not selected according to e.g. gender or smoking habits.

- Alternative form

The present given alternatives in the form can be divided into three categories:

- *Degree of acceptance*
  - Pleasant
  - Good
  - Acceptable
  - Satisfactory
  - Unpleasant
  - Unbearable

- *Easily recognised odour types*
  - woody
  - metallic
  - sweet
  - odourless

- *Personal interpretation*
  - fresh
  - humid
  - dry
  - heavy
  - stuffy
  - pungent

9.4. A critical review of case studies: Building materials identified as major sources for indoor air pollutants (Sweden)

In this publication 24 case studies are presented in which building materials are identified as major sources of emissions in buildings[209]. Each case study has been presented in order to represent a specific type of emission source and/or pollutant. The materials investigated are:

- Impregnated and untreated wood products
- Products based on linseed oil (alkyd paint and linoleum)
- Insulating materials
- Polymer materials
- Concrete and self-levelling compound
- Floor adhesives

9.5. Risques sanitaires liés aux émissions de composés organiques volatils par les produits de construction et d'aménagement intérieur (France)

In the development of the French AFSSET 2006 protocol several solid building materials were tested[79]. The tested materials include different types of floor coverings:

- Wooden floorings
- PVC floorings
- Carpet tiles

9.6. Emission of flame retardants from (consumer products and) building materials (Germany)

In this BAM research project flame retardant emission has been tested on several building materials (insulating and assembly foams)[210].
The tests were performed in emission test chambers and cells of various sizes in combination with suitable sampling and analysis methods. Emission test chambers with volumes of 0.02 m^3 (per DIN 55666) and 1 m^3 were used within this project as well as 0.001m^3 BAM emission test cells for the investigations and all operated under the same standard climatic conditions at T = 23 °C and R.H. = 50 %. The principle of mantletempering was used for all emission test chambers and cells. The documents from CEN/TC 264, WG 7 (Air properties, emissions from building materials) and CEN TC 112, WG5 (Wooden materials, formaldehyde) set the relevant technical basis for the execution of emission tests and the design of emission test chambers. The standard DIN V ENV13419, Part 1 - 3 compiled in connection with CEN TC 264, WG 7 contains the determination of emissions of volatile organic compounds (VOC) by emission test chambers and cells and the production, treatment and preparation of emission samples.
The product loading factor was calculated depending on product type and 17.4 m^3 of model room volume and 7 m^2 of floor area was used (DIN V ENV 13419-1). A unitspecific air flow rate was introduced instead of a surface-specific air flow rate for products with a non-specific surface (for

example PC systems). Test parameters (volumetric air flow rate, air flow rate, sampling volume etc.) are adjusted to the product properties accordingly.

The following flame retardants were analysed: polybrominated diphenylethers (PBDE), polybrominated biphenyls (PBB), hexabromocyclododecane (HBCD), tetrabromobisphenol A (TBBPA), chloroparaffins, and halogenated and non-halogenated organophosphate compounds (OPC). The physicochemical characteristics of the analysed emitters, which mainly belong to the semivolatile organic compounds (SVOC), require air sampling by adsorption on polyurethane foam (PUR foam). The testing time is usually at least 100 days, in some cases 200 days, in order to ensure development of a steady state which is necessary for the measurement. Sample preparation of the PUR foam takes place by soxhlet or ultrasonic bath extraction using suitable organic solvents.Identification and quantitative determination are performed by gas chromatography/mass spectrometry (GC/MS) or High Performance Liquid Chromatography (HPLC) and following UV detection.

9.7. Plasters, mortars and gypsum boards for internal use (Germany)

To minimise the burden of testing and to avoid that construction products, which have already been demonstrated to be safe for health and the environment, have to be repeatedly tested, the Mandate M/366 includes the option of exempting groups of construction products by classifying them as WT (accepted without testing) and WFT (accepted without further testing).

The research project had the task to show, how such a classification could be carried out, and which criteria or assessment methods could be applied to product groups to make sure that a high level of health and environment related protection is given[211]. For the purpose the product group of plasters, mortars and gypsum boards were chosen as example for questions related to emissions to indoor air.

9.8. Emissions from solid flooring materials (ECA N°18, Europe)

In appendix 6 of the ECA Report N°18 “Evaluation of VOC emissions from building products” (for details see section 8.1) emission data of several flooring materials are reported.

9.9. Parallel emission testing with emission test chambers and FLEC (international)

In the publication “Emission cells and comparison to small chambers for materials emission testing” an overview is made from building products tested with emission chambers and FLEC[212]. Several building products are assessed:

- Vinyl flooring
- Paints

- Lacquers
- Wood based products
- Linoleum
- Carpet

The article concludes that “both chamber and cell can provide reliable emission data under well-controlled test conditions. Extensive field experience of the FLEC emission cell since its introduction has shown that the relative ease , with which the key parameters can be controlled/reproduced, is one of the main reasons, in addition to speed, that make it suitable for use as a routine industrial quality assurance tool. Experience gained during the interlaboratory studies described, has shown the FLEC emission cell to be suitable for many emissions testing applications and to be a useful supplement to small chambers.”

9.10. “Green purchasing of building materials” (EU project RELIEF)

In work package 13 of the RELIEF project existing green purchasing guidelines for several building materials were compiled[213]. Following building materials are addressed:

- Solid wall building materials
- Wood and wooden products
- Plaster boards and plasters
- Insulating materials
- Films and seals
- Windows
- Floor coverings
- Indoor paints and varnishes

9.11. “Prioritization of building materials as indoor pollution sources” (EU project BUMA)

One of the goals of the BUMA project was to characterize the sources of hazardous compounds emitted from commonly used building materials in indoor environments across Europe[12,214].
The study concerning the measurement of emissions from the selected materials was conducted at the Joint Research Centre. Chamber tests for emission monitoring of the selected building materials followed the ECA Report No. 18 and ISO 16000 standard series.
Two kinds of chambers were used for the evaluation of the materials’ emissions. A small glass chamber of a volume of 20 l (sampling times: 3h, 1, 3, 7, 14 and 28 days) and a 30 m^3 stainless steel walk-in type environmental chamber with remote control of climatic parameters (sampling times: 3h, 1, 3 and 5/7 days) were used. The experimental conditions for all emissions measurements in the chambers were representative of indoor environments (temperature: 23 °C ± 0.5, relative humidity: 50% ± 5%, air exchange rate-ACH-: 0.5 h^{-1}. A loading factor of 0.4 m^2m^{-3} was used during the emissions chambers tests.

The two main categories of building materials included in the database are ‘’construction products’’ covered under the Construction Products Directive (CPD) and “other buildingmaterials”. The construction products include, among others, floorings (e.g. plastic, wood, tiles, linoleum), adhesives, plastic paneling (e.g. PVC, polystyrene, urea formaldehyde and melamine resigns), pressed wood products (particle boards, ply woods, MDFs) and thermal insulating materials (polystyrene and polyurethane foam insulating, urea formaldehyde foam insulating). The ‘’other building materials’’ category includes products such as carpets, wall papers, paints and varnishes. Emission data were collected for the 8 categories of construction products.

The database contains the emission data measured during the project complemented with literature data. The database contains more than 5000 emission data, for more than 300 different building materials.

9.12. Reference values for building material emissions and indoor air quality in residential buildings (Finland)

Indoor air concentrations and emissions from structures and interior materials were investigated in eight residential buildings during the time of construction and the first year of occupancy[215]. Volatile organic compounds (VOCs), formaldehyde and ammonia concentrations and emissions as well as temperature, humidity, and ventilation were measured.

The study confirmed that the Finnish material classification system provides a basis to achieve good IAQ when comparing to the target values for pollutant concentrations given by the classification (FiSIAQ 2001) in real buildings. However, suggestions for its further development are given. Based on the indoor air and emission results, reference values, i.e. normal and abnormal values, were defined for the six- and twelve month-old buildings.

9.13. Building Material Emissions Study (California)

In order to determine the effect of materials with recycled content in relation to indoor air quality, emissions data were collected for standard building materials and their alternative sustainable counterparts[216]. The study had the following four main objectives:

1. To measure emissions from standard products, and compare them to those emitted from their alternative sustainable counterparts.
2. To measure chemical emissions from tire-derived resilient flooring and compare them to those emitted from their non-tire-derived counterparts.
3. To investigate the applicability of Section 01350 as a screening tool for standard and alternative building materials.
4. To identify additional chemicals of concern to the State using the test methods and reporting procedures described in Section 01350.

Following materials were investigated:

- Acoustical ceiling panels
- Carpets
- Fiberboard

- Gypsum board
- Paints
- Particleboard
- Plastic laminates
- Resilient flooring
- Tackable wall panels
- Thermal insulation
- Wall base

9.14. Interlaboratory comparison of building material emission testing (Germany)

The interlaboratory comparison, which was performed within the search for the improvement of test chamber measurements had the purpose of determining the influence of various method parameters used for test chamber measurement across different test laboratories[217].
The entire interlaboratory comparison was divided into three steps. In the first step the analysis of liquid solutions took place, in the second, VOCs were determined in test chamber air and in the third step a complete emission test chamber measurement was carried out by the participants. The three consecutive steps are supposed to clarify the influence of the analysis, the sampling and the test chamber.

In this report it is stated that:
"As a result of the first step (analysis of 4 liquid solutions) a standard deviation of less than 20 % for 8 out of 11 substances tested was obtained. The standard deviations for dichloropropanol, caprolactam and butyl diglycol ranged up to 36 % (Section 2.4.1 of the report).

The second step, which included air sampling at a BAM test chamber, resulted in only one standard deviation value less than 20 % (11 % for styrene). The standard deviations for the other six substances were between 20 % and 36 % (Section 3.3 of the report).

In the third step, two test chamber measurements were carried out on a sealing compound in the participants' test chambers. Although a number of different test chambers (volumes between 20 and 1000 litres) with different loading factors and different air exchange rates (at the same area-specific air flow rate $q = 44\ m^3/m^2h$) were used, the standard deviations for 4 of the 7 measured VOC concentrations were between 17 % and 19 % and thus within the same range as in Step 1 and even better than for most substances in Step 2. A standard deviation of 60 % was found for the key component ethanediol, but this can be explained with the difficult analysis method for this substance. Two other substances with very low concentrations (4 $\mu g/m^3$ and 6 $\mu g/m^3$) exhibited standard deviations of 43 % and 46 % (section 4.4.1 of the report)."

For improving the test chamber measurements following recommendations were made:

- A more exact regulation of the test chamber parameters (such as the one being compiled in CEN/TC351/WG2 standard)
- Application of a uniform temperature programme for the GC

- Use of a moderately polar separating column for gas chromatography
- Regular participation of the laboratories in interlaboratory comparisons for emissions tests

9.15. Results from various scientific publications (international)

Article: *Sensory Characterization of Emissions from Materials (Denmark)*

Knudsen, H.N[1]; Clausen, G.[1]; Fanger, P. O.[1], Indoor Air, Volume 7, Number 2, June 1997 , pp. 107-115(9), Blackwell Publishing

The ***exposure-response relationship*** between the concentration of air pollutants and perceived air quality was studied for eight materials often found indoors and for a mixture of three of the materials. Samples of the materials were placed in a ventilated test chamber. The exhaust air from the test chamber was diluted with different rates of unpolluted air to obtain five different concentrations of polluted air. A sensory panel assessed the perceived quality of the five concentrations of polluted air.

Conclusions:

- The exposure-response relationship between the concentration of air pollutants and perceived air quality differed between the eight materials investigate as well as from the corresponding relationship for human bioeffluents.
- The exposure-response relationships can be described by straight lines in a log-probit plot and be defined by two constants characteristic for each material. Determination of the two constants characterizing each material requires sensory assessments at least at two pollution concentrations.
- The sensory pollution load for a material may change with the pollution concentration in the air.
- A simple measurement method based on a dilution system connected to a ventilated small-scale test chamber is proposed, to characterize the emissions from materials in sensory and chemical terms.

Article:. ***Response Relationships for Emissions from Building Products[218]*****,**

Knudsen, H. N., Valbjorn, O., Nielsen, P. A., Determination of Exposure-Response Relationships for Emissions from Building Products, Indoor Air, 8, 4 (1998) 264-275.

Abstract

Determining the ***exposure-response relationship*** between concentration of the emission from a building product and human response is recommended to evaluate their impact in sensory terms on the perceived air quality.

A practical method is proposed based on an air-dilution system connected to the exhaust of a ventilated small-scale test chamber. The method was used to determine the exposure-response relationships for *eight building products*.

For each building product, samples were placed in a test chamber. A typical room was used as a reference to calculate a building-realistic area-specific ventilation rate in the test chamber. A sensory panel assessed the immediate acceptability (Continuous acceptability scale slightly modified from Gunnarsen and Fanger (1992)) of polluted air at *four different concentrations* (due to dilution system) *3, 10 and 29 days* after samples of the building products were placed in the test chambers.
The exposure- response relationships show that the ***impact of dilution*** of polluted air on the perceived air quality ***varies between building products***. For some building products it may only be possible in practice to improve the perceived air quality marginally by increasing dilution. The results of the present study suggest that for such building products, ***source control is recommended*** (change composition of the material) as the remedy for poor indoor air quality, rather than an increase of the ventilation rate

Article: **Olfactory evaluation of indoor air quality** (Berglund B. and Lindvall T, 1979)

Threshold values give valuable information on how difficult it is to eliminate an odour problem by dilution of the polluted air. The disadvantage of these methods is that no information is given on the perceived air quality above odor threshold.

Other valuable information on odour experiments can be found in the referencelist[107,219,220,221,222,223,224,225,226,227,228,229,230].

A (non exhaustive) list of other relevant publications providing building material emission data is given below:

- Formaldehyde in the indoor environment[231]
- Interlaboratory comparison experiment on the determination of formaldehyde emitted from mineral wool board using small test chambers[232]
- Characterization of VOC and formaldehyde emissions from a wood based panel: results from an inter-laboratory comparison[233]
- VOC- and SVOC-emissions from adhesives, floor coverings and complete floor structures[234]
- VOC emissions from building products: sources, testing and emission data[235]
- Volatile organic emissions from particleboard veneered with decorative paper foil[236]
- Volatile Organic Chemical Emissions from Structural Insulated Panel (SIP) Materials and Implications for Indoor Air Quality[237]

- Comparison of formaldehyde emission from building finishing materials at various temperatures in under heating system; ONDOL[238]
- Material emission rates: literature review and the impact of indoor air temperature and relative humidity[239]
- Comparison of the substrate effect of VOC emissions from water based varnish and latex paint[240]
- Comparison of analytical techniques for the determination of aldehydes in test chambers[241]
- Emission of formaldehyde from indoor surface materials[242]

10. Relevant construction products concerning indoor air quality: products of concern

10.1. Based on CEN & EOTA mandates

A list of productTCs (and mandates) is given in Table 46. The productTCs which products are used indoor are put in bold.

A list of EOTAWGs (and mandates) is given in Table 47. The EOTA WGs which products are used indoor are also put in bold.

Several productTCs already provided information on specific information per product group. Following information is a summary of the findings mentioned in TR2 draft version[92]:

- CEN/TC 88: thermal insulating materials and products

  Products covered: thermal insulation for walls, floors and ceilings (between interior and exterior wall or as part of a pre-fabricated panel), for pipes and ducts (on outside)

  Relevant scenario for intended use: not in direct contact with indoor air (in general)
- CEN/TC 104: concrete

  Products covered: concrete and related products

  Relevant scenario for intended use: direct and not in direct contact with indoor air are possible
- CEN/TC 112: wood based panels

  Products covered: the main wood-based panel types present on the market are fibreboards, particleboards and OSB (oriented strand board) and plywood. Wood based panels are mainly used in the building sector and in the furniture industry. Besides unfaced raw boards wood based panels are overlaid e.g. covered with melamine impregnated papers or veneers on their panel surfaces.

  Relevant scenario for intended use: finising and construction products directly in contact with indoor air, sometimes covered with a thin layer
- CEN/TC 134: resilient, textile and laminate floor coverings

  Products covered: resilient, textile and laminate floor coverings (inorganic floorings such as ceramic tiles, natural stone floorings and artificial stone floorings are not part of this TC, which only includes organic materials)

  Relevant scenario for intended use: products are used indoors in large surface to volume ratio and are potential indoor air polluters
- CEN/TC 349: sealants for joints in building construction

  Products covered: sealants for joints in building construction (glass products such as glazing)

  Relevant scenario for intended use: direct contact to indoor air

CEN/TC	Title	Mandates
33	Doors, windows, shutters and building hardware	M/100 & M/108
38	Durability of wood and wood based products	not mandated under the CPD
46	Oil stoves	M/129
50	Lighting columns and spigots	M/111
51	Cement and building limes	M/114
67	Ceramic tiles	M/119 & M/121
69	Industrial valves	M/131 & M/136
72	Automatic fire	M/109
88	Thermal insulating materials and products	M/102
92	Water meters	M/131 & M/136
99	Wall coverings	M/121
104	Concrete	M/128
112	Wood-based panels	M/113
121	Welding	M/120
124	Timber structures	M/112
125	Masonry	M/116
128	Roof covering products for discontinuous laying and products for wall cladding	M/121 & M/122
129	Glass in buildings	M/135
130	Space heating appliances without integral heat sources	M/
132	Aluminium and aluminium alloys	M/120
133	Copper and copper alloys	M/120
134	Resilient, textile and laminate floor coverings	M/119
135	Execution of steel structures and aluminium structures	M/120
139	Paints and varnishes	not mandated under the CPD
154	Aggregates	
155	Plastic piping systems and ducting systems	M/118 & M/131 & M/136
163	Sanitary appliances	M/110
164	Water supply	M/131 & M/136
165	Waste water engineering	M/118
166	Chimneys, flues and specific products	M/105
167	Structural bearings	M/104
175	Round and sawn timber	M/119 & M/121
177	Prefabricated reinforced components of autoclaved aerated concrete or lightweight aggregate concrete with open structure	M/100
178	Paving units and curbs	M/119
185	Threaded and non-threated mechanical fasteners and accessoires	M/120
189	Geotextiles and geotextile-related products	M/106
191	Fixed firefighting systems	M/109
192	Fire service equipment	M/109
193	Adhesives	M/127 & M/131 & M/136
203	Cast iron pipes, fittings and their joints	M/131 & M/136
208	Elastomeric seals for joints in pipework and pipelines	M/131 & M/136
217	Surfaces for sport areas	M/119

221	Shop fabricated metallic tanks and equipment for storage and for service stations	M/131
226	Road equipment	M/111
227	Road materials	M/124
229	Precast concrete products	M/100
235	Gas pressure regulators and associated safety shut-off devices for use in gas transmission and distribution	M/131 & M/136
236	Non-industrial manually operated shut-off valves for gas and particular valves-other products	M/131 & M/136
241	Gypsum and gypsum boards	M/106
246	Natural stones	M/119 & M/121
249	Plastics	
254	Flexible sheets for waterproofing	M/103
266	Thermoplastic static tanks	M/131 & M/136
277	Suspended ceilings	M/121
295	Residential solid fuel burning appliances	M/129
297	Free-standing industrial chimneys	M/105
298	Pigments and extenders	M/128
303	Floor screeds and in-situ floorings in buildings	M/132
323	Raised access floors	M/119
336	Bituminous binders	M/124
340	Anti-seismic devices	M/132
349	Sealants for joints in building construction	not mandated under the CPD
350	Sustainability of construction works	not mandated under the CPD
BT/TF 119	Stretched ceilings	M/121
ECISS/TC 10	Structural steels - qualities	M/120
ECISS/TC 13	Flat products for cold working - Qualities, dimensions, tolerances an specific tests	M/120

Table 46: ProductTC's working under the CPD

EOTA WG	Mandate description
1	Metal anchors for concrete (heavy duty uses)
2	Metal anchors for use in concrete for fixing lightweight systems
3	Plastic anchors for use in concrete and masonry
4	Metal injection anchors for use in masonry
5	Structural sealant glazing systems
6	External thermal insulation composite systems (ETICS)
7	Non-load bearing permanent shuttering systems)
8	Mechanically fastened flexible waterproofing membranes for roofs
9	Liquid applied roof waterproofing kits
10	Internal partition kits
11	Self supporting translucent roof kits
12	Prefabricated stair kits
13	Post tensioning kits for prestressing of structures
14	Light composite woodbased beams and columns
15	Timber frame building kits
16?	Log building kits
17	Fire stopping, fire sealing and fire protective products
18	Prefabricated wood-base loadbearing stressed skin panels
19	Self supporting composite light-weight panels
20	Expansion joints for road bridges
21?	Three-dimensional nailing plates
22	Vetures (prefabricated) insulation kits and cladding kits
23	Falling rock protection kits
24	Prefabricated building units
25	Liquidapplied bridgedeck waterproof systems
26	Concrete and metal frame building kits
27	Cold storage rooms and building kits
28	Pins for structural joints
29	Watertight coverings for bathroom walls and floors/self-supporting composite light-weight panels
30	Ultra thin layer asphalt concrete
31	Inverted roof kits
32	Fire retardant products

Table 47: EOTAWGs working under the CPD[243]

10.2. Based on literature, research projects and initiatives in other countries

In a previous BBRI study - dealing with evaluation of health aspects of consumers (occupants) (and workers) - following building materials in contact with indoor air were selected as important building materials for VOC characterization[4]:

- Adhesives
- Plasters
- Mortars
- Aerated concrete
- Wood based panels (used as floor- and wall covering)
- Wooden doors, windows and staircases
- “Self levelling” flooring (“gietvloer”)
- PVC and linoleum floorcoverings
- Thermal insulation materials (PUR, XPS)
- Paints and varnishes
- Treated wood

Following (polymeric) materials used in buildings are identified as VOC sources in (international) review papers[209,244]:

- Vinyl/pvc floor covering
- Vinyl tiles
- Rubber floorings
- Soft plastic flooring
- Linoleum flooring
- Textile carpet, carpet with synthetic/pvc fibres, carpet assembly,...
- Mineral wool insulation batt
- Glass wool fibrous insulation
- Extruded polystyrene thermal, insulants
- Extruded polyethylene duct and pipe insulants
- Plastic laminated board
- Vinyl and fibre glass wallpaper, PVC foam wallpaper, ,...
- PVC wallcovering
- Vapour barriers (bituminous tar)
- Black rubber trim for jointing
- Vinyl covering
- Textile wall and floor coverings
- Acoustic partitions
- Particleboard
- Plywood panelling
- Cork floor tiles
- Paints and varnishes (surface coatings)

- Wall and floor adhesives
- Caulks
- Sealants
- Moisture repellents
- impregnated wood
- Damp-proof membranes
- Self levelling compounds

Due to their large surface area floorings are potentially one of the most important pollution sources in indoor spaces. Following list of flooring materials is considered in the AgBB/DIBt protocol which is mandatory in Germany for flooring materials[245]:

- Textile floor covering
- Resilient floor covering
- PVC – floor covering
- Linoleum – floor covering
- Floor coatings
- Parquett/ laminate floor covering
- Polyurethane – floor covering
- Polyolefine – floor covering
- Panellings
- Rigid panels (organic / anorganic)

In a recent German study concerning VOC emissions following construction products were tested[207,208]:

- Acrylic and silicone sealants
- Paste-like synthetic resin plasters
- Wood based products (chipboard, OSB board, laminate, cork parquet,...)
- Adhesives
- Lacquers
- Wall paints
- Glass fibre non-woven fabric with adhesive
- Primer on plasterboard
- Plasterboard (humid surroundings)

In the recent French AFSSET/CSTB study following building materials were considered necessary for VOC characterization[79]:

- Les panneaux de cloison
- Les plafonds et revêtements de plafonds
- Les revêtements de sol
- Les revêtements muraux
- Les éléments de cloison, de maçonnerie et les produits d'isolations

In the Finnish emission classification system following groups of building materials have the label emission class M1 and are considered as important for achieving a good (indoor) air quality[246]:

- Paving tiles
- Concrete + concrete component systems
- Steel plates
- Bricks
- Light weight aggregate blocks
- Concrete blocks
- Gypsum boards
- Chipboard
- Plywood
- Fiber panels
- Soft fiberboard
- Mediumboard
- Hardboard
- Decorative plastic laminates
- Plastic panels
- Mineral building boards
- Special panels
- Insulators
- Insulation products
- Mineral based heat insulation
- Natural fiber-based heat insulation
- Plastic insulation product
- Heat insulation, miscellaneous
- Flexible separating membranes
- Technical insulation
- Interior wall elements (concrete)
- Laminated beams
- Doors
- Sports floors
- Tiling products
- Flooring
- Wooden Flooring
- Plastic cladding
- Rubber flooring
- Laminated floors
- Carpets
- Linoleum and cork sheet and tile flooring
- Carpet underlays
- Interior cladding
- Paper and acrylic wallpapers

- Vinyl wall coverings
- Painted interior cladding surfaces
- Decorative plates
- Interior cladding panels
- Acoustic coatings
- Adhesives, mortars, fillers, + composition flooring + putty, mastics, fillers, screeds
- Adhesives
- Sealing bands
- Sealing compounds
- Waterproof coatings
- Paints and varnishes
- Special painting products, miscellaneous
- Surface protection products

In the ongoing (Phase II) Canadian study "Material Emissions and Indoor Quality Modelling" following list of (building) materials is subject of VOC characterization[247]:

- Solid and engineered wood materials: oriented strand board, particleboard, plywood, MDF & solid wood (oak, pine, maple)
- Installation materials: adhesives & caulking/sealants
- Flooring:vinyl flooring, laminate, laminate/underlay (lam 2), laminate/underlay/OSB (lam 3), linoleum, linoleum/adhesive/plywood, carpet & carpet/adhesive/concrete
- Walls: gypsum panels & vinyl-faced wall panel
- Ceilings: acoustical ceiling tile
- Interior finishing: floor wax, PUR, paint & woodstain

In California the CHPS (Collaborative for High Performance Schools, see section 8.15) lists following categories of (building) materials eligible for low-emitting material credits[248,249]:

- Flooring adhesives, sealants and concrete sealers
- Carpets
- Resilient flooring
- Wood flooring
- Paints
- Thermal insulation products
- Gypsum board
- Acoustic ceilings and wall panels
- Cabinetry
- Teacher/pupil desks and chairs
- Other composite wood products (e.g. sub-flooring)

The Greenguard Environmental Institute (see section 8.9) has indoor environmental quality specifications for following interior building products and materials[250]:

- Thermal insulation
- Ceilings: acoustic ceilings, specialty ceilings and textured ceilings

- Floorings: applicable to specialty flooring, wood flooring, resilient flooring, stone/terrazzo flooring, carpeting, access flooring and flooring underlayment.
- Floor finish: applicable to wood floor finishes and hard surface floor finishes
- Wallcoverings: applicable to wallpaper, wall fabrics, vinyl wall covering, acoustic wall finish, wood veneer wall finish, laminate surfacing
- Paints and coatings: interior painting, interior staining & finishing and special coatings
- HVAC insulation, HVAC duct & castings and air duct accessories
- Doors
- Window treatments: applicable to blinds, shutters, shades, louvers, (curtains and drapes)
- General construction materials (wood based): applicable to engineered wood, sheathing and treated woods
- General construction materials (non-wood based): applicable to plastic fabrication, plaster & gypsum board, ceramic tile, plastic tile, cut natural stone tile and concrete.

Some databases concerning building materials and emissions (or content) of dangerous substances exist in Europe:

1. INIES database (Fr)[43]: in France the environmental and health-related characteristics of building products - described in EPD (environmental product declarations) - are collected in the INIES database. Declarations of VOC emissions are gradually being implemented. The EPD's are available for the different building product families shown in Figure 30.
2. BASTA database (Sw)[46]: in Sweden a database (see Figure 31) has been created which lists the building materials that meet the requirements concerning content of very dangerous substances. The information is only available in Swedish.
3. SOPHIE database (EU)[251]: SOPHIE is the acronym for SOurces of Pollution for a Healthy Indoor Environment. It is a database of indoor pollution sources, including building materials, furnishings and ventilation-system components. The database created in 2001 was the result of the work of a vast network of laboratories in Europe developed under the sponsorship of the European Commission. Its aim was to document the most important indoor pollution sources and to create a model to establish a link between the strength of the pollution sources and the ventilation rate and its consequences in terms of the IAQ in a given space.
4. BUMA database (EU)[12]: In the context of the BUMA project a database was constructed containing up-to-date emission data for building materials. The two main categories of building materials included in the database are "construction products" covered under the CPD and "other building materials" like wall papers, paints and varnishes.

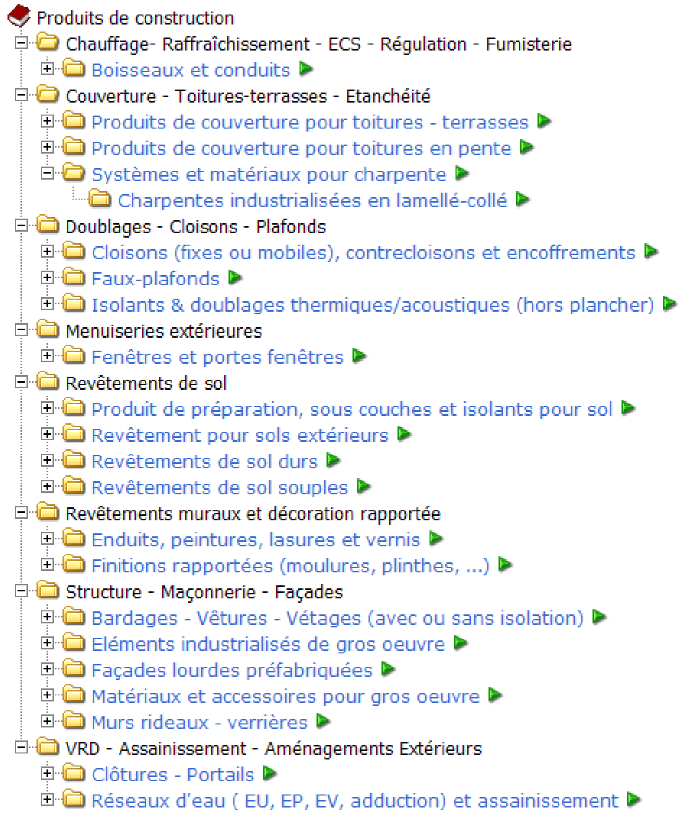


Figure 30: Product families in the INIES database

Figure 31: BASTA database (Sweden)

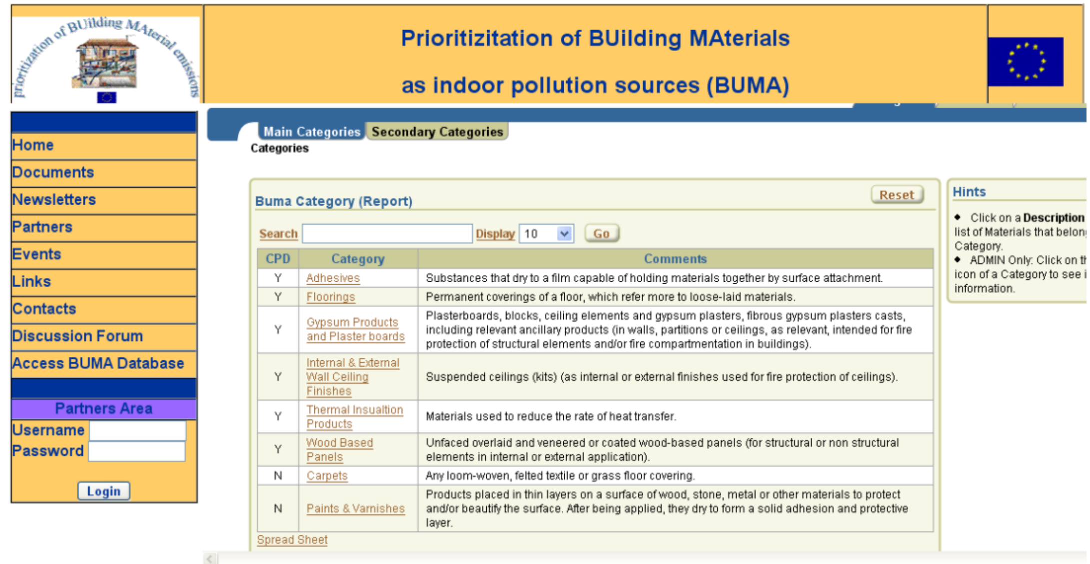


Figure 32: BUMA database (EU)

Moulds are able to degrade almost all natural and many man made materials, especially if they are hygroscopic. Even totally inorganic materials will still get mouldy as they over time absorb dust which is a good medium for especially A. fumigatus and A. versicolor.
Wood is still one of the most commonly used materials, and is highly susceptible to mould growth, already at the sawmill. Kiln drying makes the surface of the wood more susceptible to mould growth, as the surface will get a higher content of nitrogen and low molecular carbohydrates. A number of modified wood materials are commonly used, and materials such as OSB plywood and MDF are more susceptible to growth of Aspergillus, Trichoderma and Penicillium than solid wood, particle board, acylated wood and wood-polyethylene composites.
Prefabricated gypsum board is most commonly used for inner-wall material in new buildings. However due tot the paper, used to reinforce the material, the boards are highly susceptible to the growth of moulds especially to cellulytic S. chartarum.
The gypsum itself (used in plaster walls) can also support fungal growth and the susceptibility is then correlated to the relative nutrient content of the gypsum and additives that make it more hygroscopic at lower humidity's.

Many indoor surfaces are wallpapered and this increases the susceptibility of the walls as paper and the glue are good media for most indoor moulds.
Plastic materials are being increasingly used, and polyethylene and PVC are vulnerable to mould growth, as the mould utilise most plasticizers. Even fibre glass insulation and fibre glass ceiling tiles (10% urea phenol-formaldehyde resin) support fungal growth of especially A. versicolor and Penicillium spp.
Polyurethanes have been used in many composites as well as insulation materials, and some of them are highly susceptible to mould attack and they should be routinely tested for microbial degradation. Especially Paecilomyces variotii, T.harzianum and Penicillium spp are frequently growing on urea-formaldehyde foam insulation materials.

Paints can both increase and decrease the susceptibility of a given base material. Waterborne paints, which are the most commonly used in Europe due to occupational health problems with organic solvents are highly susceptible to mould growth and should be routinely tested. However the base material for paint is also important for the mould growth. Aureobasidium pullulans is the absolute most common mould on paints which it deteriorates paints. A. pullulans is often succeeding Aspergillus, Alternaria and Cladosporium on acrylic paints.
Mould growth in air filters and ventilation ducts is of special concern as the ventilation system will act as an effective carrier of the spores. In the ventilation ducts growth generally occurs on painted surfaces and especially in dust, although certain fibre glass insulation materials may support growth.

The associated fungi reported from different countries vary considerably for a number of reasons, such as different climates, materials different isolation procedures and difficulties in identifying the isolates to species level[252].
Many studies in literature indicate common fungal growth on wood and cellulose containing materials, gypsum boards, pipe insulation wall paper paints, insulation materials and floor coverings, like PVC but the reported fungal species can be different due to the environmental growth conditions encountered at the sampling place and the different isolation and identification methods used at the laboratories.

11. List of abbreviations - terminology

VOC = volatile organic compound
VVOC very volatile organic compound
SVOC= semivolatile organic compound
MVOC= microbial volatile organic compound
TVOC= total volatile organic compounds
TSVOC= total semi-volatile organic compounds
PM = particulate matter
DS = dangerous substances
WP = work package
TC = technical committee
TDS= thermal desorption
GC = gas chromatography
LC=liquid chromatography
MS = mass spectrometer
HPLC = high pressure liquid chromatography
EGDS = Expert Group on Dangerous Substances
SCC= Standing Committee on Construction
CPD= Construction Products Directive
EAS = European Acceptance Scheme (for construction products in contact with drinking water)
CEN= Comité Européen de Normalisation (European Standardisation Organisation)
AoC= Attestation of Conformity; refers to the CPD system for attesting the conformity of construction products to European technical specifications
EOTA= European Organisation for Technical Approvals
TG= Task Group
TR= Technical Report
WI= work item
FPC= factory production control
ITT= initial type testing
CMR substances= carcinogenic, mutagenic and reprotoxic substances
ETAG= European Technical Approval Guideline
CUAP= Common Understanding of Assessment Procedure for European Technical Approval without guideline (art 9.2 of the CPD)
hEN= harmonized European standard
GC/FID= Gas chromatography/flame ionization detector
HPLC= High performance liquid chromatography
GC/MD= Gas chromatography/multi-detector
GC/IT= Gas chromatography/ion trap detector
FTIR= Fourier transform infrared spectroscopy
HRGC/HRMS= High resolution gas chromatography/high resolution mass spectrometry
ICL= Indoor Climate Label (Denmark, Norway)
LCI= lowest concentration of interest (= German NIK)
AFSSET= Agence Française de Securité Sanitaire de l'Environnement et du Travail

CESAT= Comité Environnement - Santé de l’Avis Technique (Environmental and Health Committee for Technical Assessments)
CSTB= Centre Scientifique et Technique du Bâtiment
OEHHA= Office of Environmental Health Hazard Assessment
ARB= Californian Air Resources Board
GEV= Gemeinschaft Emissionskontrollierte Verlegewerkstoffe
ASTM= American Society for Testing and Materials
DSIC= Danish Society of Indoor Climate (Denmark)
NFICL= Norwegian Forum of indoor Climate Labelling (Norway)
RH= Relative Humidity
COST= European Cooperation in the field of Scientific and Technical Research
IAQ= Indoor Air Quality
BIFMA= Business and Institutional Furniture Manufacturers Association
USGBC= United States Green Building Council
LEED= Leadership in Energy and Environmental Design green building rating systems

12. Annexes

12.1. Annex 1: Belgian legislation on DS - construction

The document is based on information obtained from "FOD Economie, KMO, Middenstand en Energie. Algemene Directie Kwaliteit en Veiligheid. Afdeling Kwaliteit en Innovatie"

This report/annex is divided into seven chapters:

1. Classification of dangerous substances
2. Restrictions on dangerous substances
3. Stipulations for specific products
4. Secondary materials and waste materials used as construction materials
5. Workers safety
6. Safety data sheets
7. Additional information

1. Classification of dangerous substances

1.1. At European level

The classification, packaging and labelling of dangerous substances are regulated by directive 67/548/EEC (*) and its subsequent amendments.
(*) Council directive 67/548/EEC of 27 June 1967 on the adaptation of laws, regulations and administrative provisions on the classification, packaging and labelling of dangerous substances.

The classification, packaging and labelling of dangerous preparations are regulated by directive 1999/45/EC (**) and its subsequent amendments
(**) European Parliament and Council directive 1999/45/EC of 31 May 1999 concerning the adaptation of the laws, regulations and administrative provisions of Member States relating to the classification, packaging and labelling of dangerous preparations.

1.2. At Belgian level

At Belgian level these directives are implemented by a number of executive decrees, including:
- the Royal Decree of 24 May 1982 regulating the entry into trading of substances that could be dangerous for the person or his/her environment (Belgian State Gazette of 2 July 1982) and its amendments;
- the Royal Decree of 11 January 1993 regulating the classification, packaging and labelling of dangerous preparations with a view to placing these on the market or using them (Belgian State Gazette of 17 May 1993) and its amendments.

- the Royal Decree of 17 July 2002 amending the Royal Decree of 11 January 1993

* ***Lead***

Annex II on specific provisions for the labelling of certain preparations regulates use for paints and varnishes (cf. point 1.1. of section B of annex II of this Royal Decree). The following warning 'contains lead' must be affixed to the label of the packaging of such paints and varnishes with a lead content of more than 0.15% (expressed as weight of the metal) according to ISO standard 6503 (1984: "Paint and varnishes - Determination of total lead - flame atomc absorption spectrometric method") on such paints and varnishes.

It cannot be used for objects which children can bite on or which they can suck on. In the case of a pack of less than 125 millilitres the warning is to read as follows: "Warning. Contains lead".

* ***Chromium***

Annex II on specific preparations for the labelling of certain preparations regulates the use for cement and cement preparations (cf. point 12 of section B of annex II of this Royal Decree): "The following message 'contains hexavalent chromium. Can cause an allergic reaction' must be stated on the packaging of cement and cement preparations with a quantity of hexavalent chromium of more than 0.0002 % of the total dry weight of the cement. Unless the preparation has already been classified and labelled as a sensitivity causing substance in the sense of R 43."

2. Restrictions on dangerous substances

2.1. At European level

* Council Directive 76/769/EC of 27 July 1976 and its subsequent amendments on laws, regulations and administrative provisions of member States relating to restrictions on the marketing and use of certain dangerous substances. This directive is transposed inter alia by the Royal Decree of 25 February 1996 (vide infra 2.2.1)

* Council Directive 98/8/EC of 16 February 1998 concerning the placing of biocidal products on the market.

2.2. At Belgian level

2.2.1. Royal Decree of 25 February 1996(*)

(*) Royal Decree of 25 February 1996 restricting the marketing and use of certain dangerous substances and preparations (Belgian State Gazette of 11 April 1996)

* ***Arsenic and inorganic compounds (copper, chromium and arsenic***). According to Article 1 fourth section, the arsenic compounds cannot be used as compounds and components of preparations that are intended to make wood durable. Wood treated with a solution of inorganic

compounds of copper, chromium and arsenic (CCA), type C, cannot be used for house construction among other things.

* ***Fire-delaying substances***
The fire-delaying substances (diphenyl ether pentabromine derivative $C_{12}H_5Br_5O$, and the diphenyl ether octabromine derivative $C_{12}H_2Br_8O$) are regulated under Article 1 fifth section:
- "Cannot be brought onto the market or used as a substance or a component of substances or preparations in concentrations of over 0.1 mass percent.
- Articles cannot be brought onto the market if they, or fire-delaying components of these, contain higher concentrations than 0.1 mass percent of this substance."

* ***Chromium***
Cement and cement containing preparations may not be used or not enter the market if the content of soluble chromium (VI) in the hydrated form of the cement or preparation amounts to over 0.0002 % of the total dry weight of the cement (cf. Article 1 seventh section, Royal Decree of 15 July 2004 amending the Royal Decree of 25 February 1996 for implementation of European directive 2003/53/EC)

* ***Cadmium***
Article 4 regulates the use of cadmium:
- for the colours of final products manufactured from polyvinylchloride (cf. article 4, 1° and annex 1);
- as a stabiliser in the following end products that are manufactured from polyvinylchloride and copolymers of this: swing doors ("saloon" doors); cladding of steel plating used in construction (cf. Article 4, 2° and Annex 3).

* ***Pentachlorinated phenol (PCP)***
It is forbidden to use pentachlorinated phenol (CAS-nr. 87-86-5) and its salts and esters in concentrations of 0.1 mass percent or more in substances and preparations put on the market (article 1).

* ***Organic tin compounds***
Organic tin compounds cannot be put on the market to be used as substances and components in preparations, when they function as a biocide in growth-resistant paint (article 1 a).

* ***Nonylphenol*** $C_6H_4(OH)C_9H_{19}$ and ***Nonylphenolethoxylate*** $(C_2H_4O)_nC_{15}H_{24}O$. These substances cannot be marketed or used as a compound or component of preparations in concentrations of 0.1 % (g/g) or more, inter alia, as co-formulants in anti-growth protection products and biocides (item 9 of article 1sexies).

2.2.2. Royal Decree of 5 October 1998 (*)

(*) Royal Decree of 5 October 1998 restricting the marketing and use of certain dangerous substances and preparations (Belgian State Gazette of 17 December 1998).

* ***Creosote***

According to article 7 of the Royal Decree of 5 October 1998 substances and preparations which contain creosote among other items cannot be used to treat wood. Nonetheless, some deviations are provided for, including for treating wood in industrial installations.

* ***Benzene***

The substance does not have to be classified as carcinogenic if it can be demonstrated that it contains less than 0.1 % benzene in mass (Einecs-nr.200-753-7) (Note J as an annex to this Royal Decree).

* ***2-naphtylamine***

2-naphtylamine is regulated by the Royal Decree of 9 January 2000 amending the Royal Decree of 5 October 1998 restricting the marketing and use of certain dangerous substances and preparations (Belgian State Gazette of 24 March 2000).

Certain dangerous substances and preparations are not permitted in substances and preparations that are put on the market for sale to the general public in separate concentrations equal to or greater than 0.1 % in mass, except for 2-naphtylamine (CAS nr. 91-59-8).

This deviation for 2-naphtylamine was cancelled by the Royal Decree of 28 September 2000 amending the Royal Decree of 11 January 1993 regulating the classification, packaging and labelling of dangerous preparations with a view to marketing or using these and the Royal Decree of 5 October 1998 restricting the marketing and use of certain dangerous substances and preparations (Belgian State Gazette of 25 November 2000).

2.2.3. Royal decree of 9 July 1986 (*)

(*) The Royal Decree of 9 July 1986 regulating the substances and preparations that contain polychlorinated biphenyl and polychlorinated terphenyl (Belgian State Gazette of 31 July 1986)

The putting on the market and use of ***polychlorinated biphenyl and polychlorinated terphenyl (PCB/PCT)*** has been limited so that their complete removal can be achieved gradually.

2.2.4. Royal Decree of 5 November 1991

(*) Council Directive 89/677/EC of 21 December 1989 making the eight amendment to Directive 76/769/EC was transposed in the case of restrictions on organic tin compounds and ***mercury compounds*** by the Royal Decree of 5 November 1991 amending the Royal Decree of 5 June 1975 on storing, selling and using pesticides/herbicides and phytopharmaceutical products (Belgian State Gazette of 19 December 1991).
Note: In the context of treating wood the regulations on biocides apply as the Royal Decree of 5 June 1975 was partially rescinded by the Royal Decree of 22 May 2003 on putting biocides on the market and their use (vide infra 2.2.7)

2.2.5. Royal Decree of 20 July 2001 (*)

(*) Royal Decree of 20 July 2001 comprising a general regulation on protecting the population, employees and the environment against the danger of ***ionising radiation*** (Belgian State Gazette of 30 August 2001).

This Royal decree also applies to each intervention in the case of a radiological emergency or in the case of long-term exposure due to the after-effects of a radiological emergency or due to a former or existing treatment or a professional activity, as well as in the case of long term exposure for any reason whatsoever, including the presence of ***radon*** in homes.

2.2.6. Royal decree of 23 October 2001 (*)

(*) Royal Decree of 23 October 2001 limiting the putting on the market and use of certain dangerous substances and preparations (***asbestos***) (Belgian State Gazette of 30 November 2001)

The putting on the market and use of the following 6 fibres and products to which they are deliberately added are forbidden:
1° ***crocidolite*** CAS n° 12001-28-4
2° ***amosite*** CAS n° 12172-73-5
3° ***anthophyllite*** CAS n° 77536-67-5
4° ***actinolite*** CAS n° 77536-66-4
5° ***tremolite*** CAS n°77536-68-6
6° ***chrysotile*** CAS n° 12001-29-5

2.2.7 Royal Decree of 22 May 2003

* Royal decree of 22 May 2003 on putting biocides on the market and their use (Belgian State Gazette of 11 July 2003)

According to Article 2 of the Royal Decree of 22 May 2003 ***biocides*** must obtain a permit so that they can be put on the market and used.

The conditions for issuing a permit and the application procedure for a permit are described in chapter II of this Royal Decree.

The Royal Decree of 22 May 2003 also sets demands relating to:
- the packaging of biocides (Article 39),
- the labelling of biocides (Article 40),
- safety information pages (Article 43),
- information that must be communicated to the National Centre for the prevention and treatment of intoxications (Article 44),
- advertising for biocides (Articles 46 and 47),

- the data which manufacturers/importers of biocides must register (Article 66),
- the declaration about the quantities of biocides that are put on the market (Article 67).

The Royal Decree of 5 August 2006 stipulates the formation of a Committee advising matters concerning biocides and it amends the Royal decree of 22 May 2003.

3. Stipulations for specific products

3.1. Paints

(*) Royal Decree of 7 October 2005 for implementation of European Directive 2004/42/EC on reducing the content of ***volatile organic compounds in*** certain ***paints and varnishes*** and in products for spraying vehicles (Belgian State Gazette of 19 October 2005).

According to Article 3 of the Royal Decree of 7 October 2005 the products stated in Annex I can only be put on the market after the dates stated in Annex II if they have a VOC content that does not exceed the limits stipulated in Annex II and if they fulfill the requirements of Article 4.

The limit values concerning the content of volatile organic substances in certain paints and varnishes are determined by the Royal Decree. The limits depend on the products (excluding aerosols) and are degressive in time. Two dates are defined: 1 January 2007 and 1 January 2010.

* The law of 30 March 1926 on the use of white lead and other white lead paints (Belgian State Gazette of 22 April 1926).

The sale of ***white lead*** and other ***white lead paints*** to individuals and their fraudulent purchasing of such items, as well as fully prepared paints that contain white lead bearing colours, are forbidden.

4. Secondary materials and waste materials used as construction materials

The Flemish Government Decree of 5 December 2003 determining the Flemish regulation on the formation and management of waste sets conditions for the use of waste materials and secondary raw materials (Belgian State Gazette of 30 April 2004).
This Flemish decree covers in chapter 4 the use of waste as secondary materials. Particularly relevant in the context of the CPD is the paragraph 4.2.2. covering the conditions regarding composition for use in or as building material.
With regard to the conditions for use in or as building material, a distinction is made between the use in or as unbound granular building materials and the use in or as bound building materials. The conditions for use are essentially defined in terms of the chemical composition. Concentration and leaching characteristics of heavy metals (such as arsenic, cdmium, chromium, copper, mercury, lead, nickel and zinc), monocyclic and polycyclic aromatic hydrocarbons and

other organic materials (such as PCBs) should be below the values specified in Annex 4.2.2.A and 4.2.2.B. In Annex 4.2.2.C limits for immissionvalues in the soil are specified.
Important to note is that a list of waste materials which qualify for use as secondary materials is defined in Annex 4.1.

5. Workers safety

(*) The Royal Decree of 11 March 2002 on protecting the health and safety of employees against the risks from ***chemical agents at work*** applies to carcinogenic agents (Belgian State Gazette of 14 March 2002). Among other things, the "limit value for professional exposure" is defined: "the limit value of the time weighted average concentration of a chemical agent in the air in the individual breathing zone of an employee in relation to a specified reference period, unless described otherwise".

For information purposes, the employer is obliged to perform a risk analysis for all work where exposure to carcinogenic or mutagenic agents can occur in accordance with the Royal Decree of 2 December 1993 on protecting employees against the risks of exposure to carcinogenic or mutagenic agents at work (Belgian State Gazette of 29 December 1993).
As far as biological agents are concerned, the Royal Decree of 4 August 1996 (and its subsequent amendments) on the protection of workers from the risks related to the exposure to biological agents at work is relevant.

(*) The Royal Decree of 16 March 2006 concerns the protection of employees against the risks of exposure to ***asbestos*** (Belgian State Gazette of 23 March 2006). According to this Royal Decree the employer, inter alia, must draw up an inventory of all asbestos and all asbestos containing material in all sections of buildings and then adopt all measures to lower the associated risks.

6. Safety data sheets

Commission Directive 2001/58/EC of 27 July 2001 making a second amendment to Directive 91/155/EEC defining and laying down the detailed arrangements for the system of specific information relating to dangerous preparations in implementation of article 14 of Directive 1999/45/EC of the European Parliament and of the Council on dangerous substances in implementation of article 27 of Council directive 67/548/EEC (safety data sheets) is partially transposed by the Royal Decree of 17 July 2002 (*).

(*) Royal Decree of 17 July 2002 amending the Royal Decree of 11 January 1993 regulating the classification, packaging and labelling of dangerous preparations with a view to putting these on the market or their use (Belgian State Gazette of 29 August 2002).

The safety data sheet is mainly intended for professional users and must enable them to adopt the necessary measures to protect health, safety and the environment at work (article 12).

The Royal Decree of 18 February 2003 stipulates that information on a substance or preparation must be issued to employers on the occasion of supply and for notification to the civil servants in charge of supervising compliance with the law of 28 January 1999 on the safeguards that substances and preparations must offer for the health and safety of employees with a view to their wellbeing, as well as its executing decrees (Belgian State Gazette of 8 January 2004).

The supplier is to provide the employer with the information that he needs to perform the risk assessment and to establish regulations for prevention and safe use of the substance or preparation (including non-classified dangerous substances and preparations), including the safety data sheet, at the first delivery and later at each significant qualitative or quantitative change in the composition of the substance or preparation.

7. Additional information

* Flemish Indoor Air Decree ("Binnenmilieubesluit")

Indoor climate is as far as legislation is concerned a new topic and it is also an area with limited regulation.
Flemish Indoor Air Decree of 11 July 2004 to control health risks caused by contamination of the indoor environment.
This decree gives some guidance values in annex

I. Chemical factors
II. Physical Factors
III. Biotic factors

* Recent Belgian standards relating to indoor air:

NBN EN ISO 16000-1 (2006); Indoor air - Part 1: General aspects of a sampling strategy.

NBN EN ISO 16000-2 (2006); Indoor air - Part 2: Sampling strategy for formaldehyde.

NBN EN ISO 16000-9 (2006); Indoor air - Part 9: Determination of the emission of volatile organic compounds from building products and furnishing - Emission test chamber method.

NBN EN ISO 16000-10 (2006); Indoor air - Part 10: Determination of the emission of volatile organic compounds from building products and furnishing - Emission test cell method.

NBN EN ISO 16000-11 (2006); Indoor air - Part 11: Determination of the emission of volatile organic compounds from building products and furnishing - Sampling, storage of samples and preparation of test specimens.

12.2. Annex 2: Regulated volatile organic compounds excluding CMR-substances of category 1 and 2

Substance	CAS No.
Aromatic hydrocarbons	
Toluene	108883
Ethyl benzene	100414
Xylene, mix of o, mand pxylene isomers	1330207
pXylene	106423
mXylene	108383
oXylene	95476
Cumene	98828
nPropyl benzene	103651
1Propenyl benzene (ßmethyl styrene)	637503
1.3.5Trimethylbenzene	108678
1.2.4Trimethylbenzene	95636
1.2.3Trimethylbenzene	526738
2Ethyltoluene	611143
1Isopropyl2methylbenzene (ocymene)	527844
1Isopropyl3methylbenzene (mcymene)	535773
1Isopropyl4methylbenzene (pcymene)	99876
1.2.4.5Tetramethyl benzene	95932
nButyl benzene	104518
1.3Diisopropylbenzene	99627
1.4Diisopropylbenzene	100185
Phenyl octane and isomers	2189608
1Phenyldecane and isomers	104723
1Phenyl undecane and isomers	6742547
4Phenyl cyclohexene (4PCH)	4994165
Styrene	100425
Phenyl acetylene	536743
2Phenylpropene (αMethylstyrene)	98839
Vinyl toluene (all isomers: o,m,pmethyl styrenes)	25013154
Other alkylbenzenes, as long as individual. isomers have not to be evaluated differently	
Naphthalene	91203
Indene	95136
Aliphatic hydrocarbons	
nHexane	110543
Cyclohexane	110827
Methyl cyclohexane	108872
1.4Dimethyl cyclohexane	589902
4Isopropyl1methylcyclohexane	cis : 6069983 / trans: 1678826
C7C16 saturated naliphatic hydrocarbons	
Terpenes	
3Carene	498157
αPinene	80568
ßPinene	127913
Limonene	138863
Other terpene hydrocarbons	
Aliphatic alcohols	
Tertbutanol, 2methylpropanol2	75650
2Methyl1propanol	78831
1Butanol	71363

1Pentanol	71410
1Hexanol	111273
11 Substance	CAS No.
Cyclohexanol	108930
2Ethyl1hexanol	104767
1Octanol	111875
4Hydroxy4methylpentane2on (diacetone alcohol)	123422
C4 C_{10} saturated naliphatic alcohols	
Aromatic alcohols	
Phenol	108952
Butylated hydroxytoluene	128370
Benzyl alcohol	100516
Glycols, Glycolethers	
Propylene glycol (1,2Dihydroxypropane)	57556
Ethandiol	107211
Ethylene glycolmonobutylether	111762
Diethylene glycol	111466
Diethylene glycolmonobutylether	112345
2Phenoxyethanol	122996
Ethylene carbonate	96491
1Methoxy propanol2	107982
2.2.4Trimethyl1.3pentane diol, monoisobutyrate (Texa-nol®)	25265774
Butyl glycolate	7397628
Diethylene glycol monomethyl ether acetate	124174
Dipropylene glycol monomethyl ether	34590948
2Methoxyethanol	109864
2Ethoxyethanol	110805
2Propoxyethanol	2807309
2Methylethoxyethanol	109591
2Hexoxyethanol	112254
1,2Dimethoxyethan	110714
1,2Diethoxyethan	73506931
2Methoxyethyl acetate	110496
2Ethoxyethyl acetate	111159
2Butoxyethyl acetate	112072
2(2Hexoxyethoxy)ethanol	112594
1Methoxy2(2methoxyethoxy)ethan	111966
2Methoxy1propanol	1589475
2Methoxy1propyl acetate	70657704
Propilene glycol diacetate	623847
Dipropylene glycol	110985 / 25265718
Dipropylene glycolmonomethyl ether acetate	88917220
Dipropylene glycolmononpropylether	29911271
Dipropylene glycolononbutylether	29911282 / 35884425
Dipropylene glycolmonotbutylether	132739312 (Mixture)
1,4Butandiol	110634
Tripropylene glycolmonomethyl ether	20324338 / 25498491
Triethylene glycoldimethyl ether	112492
1.2.Propylene glycoldimethyl ether	7778850
Aldehydes	
Pentanal	110623
Hexanal	66251
Heptanal	111717
2Ethylhexanal	123057

Octanal	124130
Nonanal	124196
Decanal	112312
2Butenal (crotonaldehyde, cistransmix)	4170303 / 123739 / 15798648
2Pentenal	1576870 / 764396 / 31424041
2Hexenal	16635544 / 6728263 / 505577 / 1335393
2Heptenal	2463630 / 18829555 / 29381666
2Octenal	2363895 / 25447692 / 20664464 / 2548870
2Nonenal	2463538 / 30551156 / 18829566 / 60784318
2Decenal	3913711 / 2497258 / 3913813
2Undecenal	2463776 / 53448070
Furfural	98011
Substance	CAS No.
Glutardialdehyde	111308
Benzaldehyde	100527
Ketones	
Ethylmethylketone	78933
3Methylbutanone2	563804
Methylisobutylketone	108101
Cyclopentanone	120923
Cyclohexanone	108941
2Methylcyclopentanone	1120725
2Methylcyclohexanone	583608
Acetophenone	98862
1Hydroxyacetone (2 Propanone, 1hydrocy)	116096
Acids	
Acetic acid	64197
Propionic acid	79094
Isobutyric acid	79312
Butyric acid	107926
Pivalic acid	75989
nValeric acid	109524
nCaproic acid	142621
nHeptanoic acid	111148
nOctanoic acid	124072
2Ethylhexane acid	149575
Ester and Lactones	
Isopropyl acetate	108214
Propyl acetate	109604
2Methoxy1methylethyl acetate	108656
nButyl formiate	592847
Methyl methacrylate	80626
Other methacrylates	
Isobutyl acetate	110190
1Butyl acetate	123864
2Ethylhexyl acetate	103093
Methyl acrylate	96333
Ethyl acrylate	140885
nButyl acrylate	141322
2Ethylhexyl acrylate	103117
Other acrylates (acrylic acid ester)	
Dimethyl adipate	627930
Dibutyl fumarate	105759
Dimethyl succinate	106650
Dimethyl glutarate	1119400

Hexamethylene diacrylate	13048334
Maleic acid dibutylester	105760
Butyrolactone	96480
Chlorinated hydrocarbons	
Tetrachloroethene	127184
Further VOC	
1.4Dioxan	123911
Caprolactam	105602
Nmethyl2pyrrolidon	872504
Octamethylcyclotetrasiloxane	556672
Hexamethylenetetramine	1009700
2Butanonoxime	96297
Tributyl phosphate	126738
Triethyl phosphate	78400
5Chloro2methyl2Hisothiazol3one (CIT)	26172554

12.3. Annex 3: Carcinogenic volatile organic compounds

Substance	CAS No.
Acrylnitrile	107-13-1
5-Allyl- 1,3-benzodioxol	94-59-7
Benzol	71-43-2
Bis(chlormethyl)ether	542-88-1
4-Chloraniline	106-47 -8
4-Chlorbenzotrichloride	5216-25-1
1-Chlor-2,3-epoxypropane	106-89-8
4-Chlor-o-toluidin	95-69-2
a-Chlortoluol	100-44-7
1,2-Dibrom-3-chlorpropane	96-12-8
1,2-Dibromethane	106-93-4
2,3-Dibrompropan-l-ol	96- 13-9
1,4-Dichlorbut-2-en	764-41 -0
2,2'-Dichlordiethylsulfid	505-60-2
1,2-Dichlorethane	107-06-2
1,3-Dichlor-2-propanol	96-23-1
1,3-Dichlorpropene (cis- und trans-)	542-75-6
1,2,3,4-Diepoxybutane	1464-53-5
Dimethylcarbamoylchlorid	79-44-7
1,2-Dimethylhydrazin	540-73-8 2
Di methylsulfate	77-78-1
1-Epoxyethyl-3,4-epoxycyclohexane	106-87 -6
1,2-Epoxy-3-phenoxypropane	122-60-1
2,3-Epoxy- 1-propanol	556-52-5
Hydrazin	302-01-2
2- Methoxyaniline	90-04-0
6-Methoxy-m-toluidine	120-71-8
(Methyl-O NN-azoxy) methylacetate	592-62-1
4-Methyl-m-phenylendiamine	95-80-7
2-Nitroanisol	91-23-6
2-Nitropropane	79-46-9
N-Nitrosodi-n-butylamine	924-16-3
N-Nitrosodietha nolamine	1116-54-7
N-Nitrosodiethylamine	55-18-5
N-Nitrosodimethylamine	62-75-9
N-Nitrosodi-i-propylamine	601-77-4
N-Nitrosodi-n-propylamine	621-64-7
N-Nitrosoethylphenylamine	612-64-6
N-Nitrosomethylethylamine	10595-95-6
N-Nitrosomethylphenylamine	614-00-6
N-Nitrosomorpholine	59-89-2
N-Nitrosopiperidine	100-75-4
N-Nitrosopyrrolidine	930-55-2

12.4. Annex 4: Updates on the Danish-Norwegian concept, the Finnish concept, the German concept and the French concept from the 2007 Berlin Conference “Construction products and indoor air quality”

Within the scope of following new tendencies, new methodologies in the area of product emission testing, VITO attended the conference “Construction products and indoor air quality” in Berlin. In the first session, policy approaches towards this subject were discussed. This was followed by an overview of 4 European concepts to identify and limit emissions from construction products, namely DICL, M1, AgBB and CESAT. Detailed information was given on these different concepts in separate rooms, where they were discussed. Subsequently there was a plenary discussion of the main issues of the different debates about the concepts. n the fourth session a discussion was held about selected aspects of the practical implementation of emissions testing of construction products. The conference ended with a panel discussion about the lessons learned from this conference.

All the presentations from the Berlin conference (June 2007) “Construction Products and Indoor Air Quality” can be downloaded from URL:
http://www.bmu.de/english/miscellaneous/doc/39600.php

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