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A voluntary evaluation scheme of the environmental and health-based characteristics of building products in France

F. Maupetit¹, O. Ramalho, E. Robine and C. Cochet

Centre Scientifique et Technique du Bâtiment (CSTB)
Sustainable Development Department – Health Division
84, avenue Jean Jaurès – Champs-sur-Marne – F-77447 Marne-la-Vallée cedex 2 - France

1. INTRODUCTION

Since there was almost no information available in France on the environmental properties and on the emissions to indoor air of building products placed on the market, CSTB proposed a global evaluation scheme of the environmental and health-based characteristics of building products. This evaluation scheme has been introduced in France in 2003, on a voluntary basis, as a complement of the Technical Agreement procedure (Avis Technique in French) for the evaluation of the fit for use properties of building products.

The environmental properties are characterized through an Environmental Product Declaration (EPD) using a French experimental standard based on the Life Cycle Analysis (LCA) of building products.

The selection of the health-based characteristics of building products to be documented in the evaluation scheme is mainly based on the essential requirement n° 3 of the Construction Product Directive.

The Directive 89/106/EEC (1) on the approximation of laws, regulations and administrative provisions of the Member States related to construction products (hereinafter referred to as « Construction Products Directive » or CPD) stipulates that construction products placed on the market are fit for their intended use, that is to say that they have such characteristics that the works in which they are to be incorporated, assembled, applied or installed, can, if properly designed and built, satisfy essential requirements.

Annex 1 of the CPD gives the following definition of the essential requirement n° 3 « Hygiene, health and the environment »: the construction work must be designed and built in such a way that it will not be a threat to the hygiene or health to the occupants or neighbours, in particular as a results of the giving-off of toxic gas, the presence of dangerous particles or gases in the air, the emission of dangerous radiation.

The Interpretative Document (2) identifies aspects of works where hygiene, health and the environment may be concerned, and identifies products and product families, and characteristics relating to their satisfactory performance where harmonized standards are required. In this Interpretative Document, essential requirement n° 3 is developed according to five specific aspects:

- ✓ Indoor environment,
- ✓ Water supply,
- ✓ Waste water disposal,
- ✓ Solid waste disposal,
- ✓ Outdoor environment.

¹ Contact author email : f.maupetit@cstb.fr

The first aspect of the requirement is concerned with providing a healthy indoor environment for occupants and users of works. The design and execution of construction work should take into account:

- ✓ Thermal environment,
- ✓ Lightning,
- ✓ Indoor air quality,
- ✓ Dampness,
- ✓ Noise.

The requirement is concerned with the elimination or control of pollutants in the indoor environment. Therefore, the construction works must provide a healthy indoor environment for occupants and building users, taking account of pollutants including:

- ✓ Metabolic products (e.g.: water vapour, carbon dioxide, odours, etc.),
- ✓ Combustion products,
- ✓ Tobacco smoke,
- ✓ Volatile organic compounds (also including formaldehyde),
- ✓ Non-viable particles (respirable and non respirable fibers and suspended particles),
- ✓ Viable particles (including bacteria and fungi),
- ✓ Radon and radioactive substances emitting gamma radiation.

According to the Interpretative document, indoor pollutants can be controlled by the control of sources and the control of air by ventilation, filtration or absorption. Sources control can be achieved by eliminating or limiting the use of materials which may release pollutants, and the use of which results in concentrations greater than acceptable limits. The characteristics necessary for satisfactory performance in relation to health, hygiene and the environment are listed below. Harmonized technical specifications are required to measure these characteristics or to calculate performance where technology permits:

- ✓ VOC and formaldehyde emissions,
- ✓ Susceptibility to the growth of harmful micro-organisms,
- ✓ Radioactive emissions.

Concerned building products are those for which emissions of pollutants to indoor air are possible. Such products include materials used for flooring, partition, walls and wall lining, ceilings, insulating materials, paints and varnishes, timber preservatives, adhesives, fillers, damp-proof membranes, electric cables and fittings, coating for floor screeds, masonry, putties, etc. Products characteristics apply to all product families and systems.

This global evaluation scheme has to be considered as a general pattern which can apply for most of building products families. Nevertheless, if necessary, particular specifications could also be documented for some building products families (e.g., emissions of fibres, emissions of SVOC, etc.).

2. ENVIRONMENTAL PRODUCT DECLARATION

In the proposed evaluation scheme, the environmental characteristics of building products along their whole life cycle are declared using the specific standard:

- ✓ NF P 01-010: Environmental quality of construction products – Environmental and health declaration of construction products (AFNOR, December 2004).

This standard deals with the general identification, quantification and organisation of the data collected along the life cycle of building products concerning the different fluxes received from or emitted to natural environments. Major considered fluxes, including possibilities of recycling or valorisation, are:

- Consumption of natural energetic or non energetic resources, of water and of energy,
- Emissions to air, to groundwater, to soil,
- Waste production.

Then, the standard presents a methodology aimed at estimating the contribution of building products to the global environmental impact of a construction work. This contribution can be expressed as environmental impacts of the product, such as:

- Consumption of natural resources,
- Consumption of water,
- Consumption of energy,
- Contribution to climatic change,
- Contribution to atmospheric acidification,
- Contribution to stratospheric ozone layer destruction,
- Contribution to tropospheric ozone production,
- Air, soil and groundwater pollution,
- Waste production,
- Modification of bio diversity.

3. VOC AND FORMALDEHYDE EMISSIONS FROM BUILDING PRODUCTS

In the proposed evaluation scheme, this criteria has to be documented for all building product families.

3.2. Characterization of VOC and formaldehyde emissions

For the determination of VOC and formaldehyde emissions from building products, CEN TC264/WG7 (Indoor air quality – Emission of chemical substances from building materials) prepared the horizontal

standard prEN 13419 (for all building products, except wood-based panels²). This European pre standard describes the procedures for preparation of building products test specimen (prEN 13419-3) and for conditioning of test specimen under controlled conditions (clean air supply, air exchange rate, temperature, relative humidity, loading factor) in emission test chamber (prEN 13419-1) or in emission test cell (prEN 13419-2):

- ✓ prEN 13419-1 : Building products – Determination of the emission of volatile organic compounds – Part 1 : Emission test chamber method (CEN, 2002),
- ✓ prEN 13419-2 : Building products – Determination of the emission of volatile organic compounds – Part 2 : Emission test cell method (CEN, 2002),
- ✓ prEN 13419-3 : Building products – Determination of the emission of volatile organic compounds – Part 3 : Procedure for sampling, storage of samples and preparation of test specimens (CEN, 2002),

Formaldehyde and VOC emissions are calculated from concentrations measured at the emission test chamber (or cell) outlet according to the standards prepared by ISO TC146/SC6 (Air quality – Indoor air) :

- ✓ ISO 16000-3 : Indoor air – Part 3 : Determination of formaldehyde and other carbonyl compounds – Active sampling method (ISO, 2001),
- ✓ ISO 16000-6 : Indoor air – Part 6 : Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID (ISO, 2004).

After the final voting stage, CEN standards 13419 (Parts 1-3) will be taken over by ISO as prEN ISO 16000 (Parts 9-11).

Therefore, CEN or ISO horizontal standards are already available for conditioning of solid, liquid or composite building products in emission test chamber (prEN 13419-1) or cell (prEN 13419-2) and for the measurement of formaldehyde emissions using high performance liquid chromatography (ISO 16000-3) and VOC emissions using thermal desorption and gas chromatography equipped with mass spectrometry and flame ionization detector (ISO 16000-6).

3.3. Evaluation of VOC and formaldehyde emissions

A procedure for the assessment of chemical emissions from solid flooring materials was presented in 1997 (3). This procedure has been established by consensus of experts within the framework of a European Collaborative Action “Indoor Air Quality & its Impact on Man” (ECA/IAQ) and can be extended to all solid products. The ECA/IAQ (1997) report outlines the principles of a common European scheme for the evaluation of VOC emissions from building products with respect to their potential effects on health and comfort.

This procedure consists of the following steps and is summarized in Table 1:

² For the determination of formaldehyde emissions from wood-based panels, the following standard should be used: ENV 717-1 – Wood-based panels – Determination of formaldehyde release – Part 1: Formaldehyde emission by the chamber method (CEN, 1998).

- ✓ Determination of emission factors of individual VOC and of TVOC (total volatile organic compounds) using emission test chambers or cells,
- ✓ Modelling of indoor relevant VOC and TVOC exposure concentrations using simple exposure scenario (including product loading factor and ventilation conditions)
- ✓ Toxicological evaluation of the indoor relevant VOC and TVOC exposure concentrations (using available air quality guidelines and lower concentrations of interest (LCI) with which relevant indoor concentrations are compared),
- ✓ Sensory evaluation of the material emissions (not detailed in this paper).

Conditioning of test specimen in emission test chamber or cell	ECA/IAQ (1997) protocol criteria for exposure concentrations
Day 0	Test specimen preparation and immediate introduction in emission test chamber or cell
Day 1	Lifelong risk for measured carcinogens $< 10^{-4}$
Day 3	TVOC $< 5000 \mu\text{g.m}^{-3}$
Day 28	<p>Lifelong risk for measured carcinogens $< 10^{-5}$</p> <p>TVOC $< 200 \mu\text{g.m}^{-3}$</p> <p>For individual VOC with concentrations $> 5 \mu\text{g.m}^{-3}$:</p> <ul style="list-style-type: none"> - VOC with LCI: $R = \sum C_i / \text{LCI} < 1$ - VOC without LCI: $\sum C_{ni} < 20 \mu\text{g.m}^{-3}$

Table 1: Scheme of the evaluation procedure for VOC emissions from solid building products (ECA/IAQ, 1997)

If the tested product fulfils all criteria of the protocol, its potential impact on occupants' health is considered as acceptable and the building product is evaluated as a "low emission" product.

4. ODOUR EMISSIONS FROM BUILDING PRODUCTS

In the proposed evaluation scheme, this criteria is optional.

For the determination of odour emissions from building products, the emission test chamber method can also be used (in parallel with VOC emissions characterization):

- ✓ prEN 13419-1 : Building products – Determination of the emission of volatile organic compounds – Part 1 : Emission test chamber method (CEN, 2002),
- ✓ prEN 13419-3 : Building products – Determination of the emission of volatile organic compounds – Part 3 : Procedure for sampling, storage of samples and preparation of test specimens (CEN, 2002),

Odour emissions of building products are characterized according to their odour intensity, using the French experimental standard:

- ✓ NF X 43-103 : Air quality – Olfactometric measurements – Measurement of the odour of gaseous effluent – Supra-threshold methods (AFNOR, June 1996).

Test results are expressed in terms of odour intensity (equivalent to a butanol gas phase concentration in ppmv).

5. APTITUDE OF CONSTRUCTION PRODUCTS FOR GROWTH OF HARMFUL MICRO-ORGANISMS

Two types of micro-organisms can be frequently found indoors: fungi and bacteria. Some of those micro-organisms can cause damage to occupant's health and/or to the building. Therefore, specific methods are necessary for the determination of the capacity of building products for growth of fungi and of bacteria.

5.2. Aptitude for growth of fungi

In the proposed evaluation scheme, this criteria is examined for all building product families.

As there are no available European standards, CSTB developed a method for the characterization of the ability of building products for growth of fungi (4). This method is adapted from following standards:

- ✓ EN ISO 846: Plastics – Evaluation of the action of micro organisms (ISO, 1997),
- ✓ NF V 18-112: Animal food stuffs – Determination of ergosterol content (AFNOR, 1991).

The principle of this method consists, under controlled conditions of temperature and relative humidity, in the generation of fungal aerosols representative of indoor environments, the characterization of aerosols in terms of concentrations and size distribution and the impact of aerosols on building products. Fungal strains selected for this method are:

- *Penicillium brevicompactum* (IHEM 04891),
- *Cladosporium sphaerospermum* (IHEM 03169),
- *Aspergillus niger* (IHEM 05077).

At the end of the test, fungal growth on material surfaces is evaluated using microscopic and biochemical techniques. Tests are performed on two set of specimens: material specimens fouled with nutrients and clean material specimens (not fouled).

On the basis of this method, test results are expressed in the following way:

- No fungal growth on clean specimens and no fungal growth on fouled specimens: **fungistatic property** of the tested product,
- No fungal growth on clean specimens and observed fungal growth on fouled specimens: **inert property** of the tested product,
- Observed fungal growth on clean specimens.

5.3. Aptitude for growth of bacteria

In the proposed evaluation scheme, this criteria is optional. It is examined for building product which will be installed in specific indoor environments with a particular focus on cleaning procedures and hygiene control (e.g. hospitals, schools, food industry, etc.).

CSTB also developed a method for the characterization of the ability of building products for growth of bacteria (5,6). This method is adapted from following standard:

- ✓ EN ISO 846: Plastics – Evaluation of the action of microorganisms (ISO, 1997).

The principle of this method consists, under controlled conditions of temperature and relative humidity, in the generation of bacterial aerosols representative of indoor environments, the characterization of aerosols in terms of concentrations and size distribution and the impaction of aerosols on building products. Bacterial strains selected for this method are:

- *Enterococcus faecalis* (Institut Pasteur Collection strain 10.30.15),
- *Pseudomonas fluorescens* (Institut Pasteur Collection strain 56.90).

At the end of the test, bacterial growth on material surfaces is evaluated using microscopic techniques. Tests are performed on two set of specimens: material specimens fouled with nutriment and clean material specimens (not fouled).

On the basis of this method, test results are expressed in the following way:

- No bacterial growth on clean specimens and no bacterial growth on fouled specimens: **bacteriostatic property** of the tested product,
- No bacterial growth on clean specimens and observed bacterial growth on fouled specimens: **inert property** of the tested product,
- Observed bacterial growth on clean specimens.

6. EMISSIONS OF NATURAL RADIOACTIVITY FROM BUILDING PRODUCTS

Materials derived from rock and soil contains natural radionuclide of the Uranium (^{238}U) and Thorium (^{232}Th) series. The purpose of setting controls on the radioactivity of building materials is to limit the radiation exposure due to materials with enhanced or elevated levels of natural radionuclide. Materials possibly causing exposure above recommended annual external gamma excess dose (0.3 mSv) are concrete, clay bricks, natural stone and gypsum boards (if Radium rich by-product gypsum is used).

6.2. Characterization of natural radioactive emissions

The principle of this kind of measurements is based on the determination of activity concentrations (in Bq.kg^{-1}) of radionuclide from Uranium and Thorium series: Thorium (^{232}Th), Radium (^{226}Ra) and Potassium (^{40}K).

Actually, there is no European standard for the characterization of natural radioactive emissions from building products. Within Europe, there is an Austrian standard available:

- ✓ ÖNORM S 5200 : Radioaktivität in Baustoffen (Österreichisches Normungsinstitut, 1996).

6.3. Evaluation of natural radioactive emissions from building products

A European expert group from Radiation Protection 112 examined the issue of regulatory control of building materials with regard to their content of naturally occurring radionuclide and developed a guidance aimed at providing a reference to the European Commission when considering possible regulatory initiatives at Community level (7).

Its principle is based on measurements of activity concentrations of Thorium (^{232}Th), Radium (^{226}Ra) and Potassium (^{40}K) in building products. An appropriate dose assessment can be performed using activity concentrations for the calculation of the annual excess gamma dose received (in mSv) by an occupant of a model room. This simple dose assessment takes into account the intended use of the product (e.g.: all structures (floor, ceiling and walls) scenario or walls only scenario, etc.).

Therefore, test results can be expressed in the following way:

- Activity concentrations of ^{232}Th , ^{226}Ra and ^{40}K (in Bq.kg^{-1}),
- Annual excess gamma dose received (in mSv).

7. CONCLUSIONS

A global evaluation scheme of environmental and health-based characteristics of building products has been introduced in France by CSTB in 2003. It is proposed, on a voluntary basis, as a complement of the Technical Agreement procedure (Avis Technique in French) for the evaluation of the fit for use properties of building products.

The global environmental characteristics of building products along their whole life cycle are described through an Environmental Product Declaration, according to the NF P 01-010 French standard.

On the basis of essential requirement n° 3 of the CPD, the health-based properties of building products in use, in relation with emissions to indoor air are also investigated in details. The building products characteristics necessary for satisfactory performance in relation to the « Indoor air quality » aspect of essential requirement n° 3 of the CPD are:

- ✓ VOC and formaldehyde emissions,
- ✓ Susceptibility to the growth of harmful micro-organisms (fungi and bacteria),
- ✓ Natural radioactive emissions.

VOC and formaldehyde emissions from solid, liquid and composite building products are characterized using the prEN 13419 and ISO 16000 series standards. Chemical emissions of solid products are subsequently evaluated on health based criteria using the protocol proposed by the European Collaborative Action (ECA/IAQ, 1997).

In parallel to the characterization of chemical emissions of building products, the odour intensity can be described using the French NF X 43-103 standard.

The aptitude of building products for growth of fungi and bacteria under controlled conditions is characterized with CSTB specific test methods derived from the EN ISO 846 standard for plastics. Those methods appear to be particularly efficient and sensitive.

Finally, the natural radioactive emissions of building products are characterized by the measurement of activity concentrations of Thorium (^{232}Th), Radium (^{226}Ra) and Potassium (^{40}K). Those emissions are subsequently evaluated according to the European guidance report from Radiation Protection 112, based on a simple dose assessment model.

8. REFERENCES

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