Environmental Impact Assessment Review 43 (2013) 49–55

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

Introduction of a method for presenting health-based impacts of the emission from products, based on emission measurements of materials used in manufacturing of the products

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ARTICLE INFO

Article history:
Received 14 December 2012
Received in revised form 21 May 2013
Accepted 29 May 2013
Available online 23 June 2013

Keywords:
Material emission
Indoor air quality
Furniture
Environmental product declaration
Addition of emission
Health related assessment

ABSTRACT

A method for presenting the health impact of emissions from furniture is introduced, which could be used in the context of environmental product declarations. The health impact is described by the negative indoor air quality potential, the carcinogenic potential, the mutagenic and reprotoxic potential, the allergenic potential, and the toxicological potential.

An experimental study of emissions from four pieces of furniture is performed by testing both the materials used for production of the furniture and the complete piece of furniture, in order to compare the results gained by adding emissions of material with results gained from testing the finished piece of furniture.

Calculating the emission from a product based on the emission from materials used in the manufacture of the product is a new idea. The relation between calculated results and measured results from the same products differ between the four pieces of furniture tested. Large differences between measured and calculated values are seen for leather products. More knowledge is needed to understand why these differences arise.

Testing materials allows us to compare different suppliers of the same material. Four different foams and three different timber materials are tested, and the results vary between materials of the same type. If the manufacturer possesses this type of knowledge of the materials from the subcontractors it could be used as a selection criterion according to production of low emission products.

1. Introduction

Studies covering the life cycle of materials and products from cradle to grave have been carried out over the last 10 years. The number of studies is enormous. The main focus is energy consumption and energy related impact categories, i.e. global warming, acidification, eutrophication, depletion of the ozone layer and depletion of non-renewable resources. The impact on humans, e.g. the human toxicology, is only addressed to a limited degree or not at all, however.

The idea behind life cycle assessments (LCA) is that all relevant environmental aspects of the product throughout its life cycle should become part of the assessment. ISO 14040 is a frequently used definition of LCA, and includes the following life cycle stages: acquisition of raw materials, distribution and transportation, production and use of fuels, electricity and heat, use and maintenance of products, and recovery of used products. Human health effects, i.e. occupational health effects or indoor air exposure, have been omitted until recently (Demou et al., 2009; Hellweg et al., 2005, 2009; Jönsson, 2000; Skaar and Jørgensen, 2013), even though both *production* and *use and maintenance of product* are life cycle stages in which emissions have an impact on human health. The influence on indoor air quality by materials and products is well known in the field of indoor climate, where one of the focus areas is improvement of indoor air quality, including ventilation and reduction of pollution sources that affect indoor air quality.

Use of low-emission materials and documentation of low emission from materials are well-established subjects when it comes to indoor air quality (Wolkoff, 2003a). This is used by labelling systems like Blue Angel, Danish Indoor Climate Labelling, Emission Classification of Building Materials, the AgBB scheme, and Natureplus in Europe; Greenguard and BIFMA in the US; and the Hong Kong Green Label Scheme in Asia (AgBB, 2010; BIFMA, 2008; Blue Angel, 2008; Danish Society of Indoor Climate, 2003; Finnish Society of Indoor Air Quality and Climate, 2000; Green Council, 2012; Greenguard Environmental Institute, 2011; Natureplus, 2008). It is also used in international standards for ventilation rates (ASHRAE, 2004; CEN, 2007) and by certification systems for buildings like LEED and BREEAM (Building Research Establishment, 2012; U.S. Green Building Council, 2012).

Environmental product declaration, EPD, is a method for documentation of products' environmental influence. The method is based on the principle behind LCA, namely that the final declaration should reflect the sum of the environmental influence of all materials used, from raw material extraction and raw material production, through production by the supplier and actual production, to transportation and

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http://dx.doi.org/10.1016/j.eiar.2013.05.008

disposal. The goal of the EPD is to be a neutral system for comparing the environmental profiles of different products.

In the context of EPD/LCA material resources, energy consumption, emissions to air and water, and waste produced during these processes are all included. These factors are called *life cycle inventories* and are combined in the EPD to *environmental impacts*: ozone layer depletion potential, eutrophication potential, global warming potential, acidification potential, photochemical oxidation, and content of heavy metals. The input data to the EPD are obtained from large databases that contain data from datasets of materials, construction, and transport processes.

The labelling schemes focus on test-chamber evaluation of the product. The manufactured product is placed in a conditioned test-chamber with a controlled flow of clean air, and the pollution content of the exhaust air from the chamber is subsequently analysed. The result is expressed in terms defined by the actual labelling scheme. Typically, the labelling schemes have defined certain categories of pollutants with associated threshold values that should be met in order to earn a label such as "emission of formaldehyde below 0.0135 ppm 7 days after start of the evaluation period". The criteria are mainly emission-demands for defined categories of chemical compounds. Some of the labelling schemes employ both concentration/health-based criteria and environmental criteria; other labelling schemes only focus on indoor environment. The concentration/health-based evaluation criteria differ between the labelling systems as well as between the time-schedules for testing, however.

A declaration of the environmental impact is demanded in governmental purchasing e.g. in Norway, and this has forced the development of EPDs in the industry. The industry encounters different demands from their customers; environmental requirements constitute one of them, health-based issues constitute another. The Norwegian furniture industry has started using EPD as a tool for environmental declaration, but they experience demands for health-based information from consumers as well. The research project "DATSUPI" is a project involving four furniture manufacturers and focuses on the development of an expanded EPD that includes health-based information. The result should be a method that is useful for theoretical calculations applicable to the product development phase, and to definitive calculations and formulation of EPDs. The challenge has been to include health related assessments of the products in the EPD-context while retaining the frame of reference to existing material labelling systems with a focus on indoor air.

The purpose of this study was to develop a method for evaluating the health impact of products/materials that is useful for introduction to the EPD framework. The method should be based on and be comparable with existing labelling schemes that have a focus on indoor air quality. An experimental study of the health impacts of four pieces of furniture is performed by testing both materials used for production of the furniture and the complete piece of furniture, in order to compare the results obtained by adding emission of material with results from testing complete pieces of furniture.

2. Theory

Eight existing labelling schemes are compared and used as basis for the health impact categories: Emission classification of building materials (M1), Danish Indoor Climate Labelling, Blue Angel, the AgBB-scheme, Natureplus, Greenguard, BIFMA, and the Hong Kong Scheme.

While the test chamber method is widespread there is still a certain diversification as to which criteria are used for assessing the emission. The two chemical analyses most typically used are analyses of aldehydes and of volatile organic compounds (VOC). Small differences exist between European systems (ISO and EN standards) and labelling systems from US/Abroad (ASTM standards), but regardless of the standard system both single aldehydes and single VOCs could be reported, and united values such as total volatile organic compounds (TVOC) or semi-volatile organic compounds (SVOC) could also be calculated from the analyses.

Measurements of VOCs and aldehydes are called emission-measurements. The evaluation criteria used by the labelling schemes are combinations of emission criteria and health-based indices such as the one used in the LCA analyses for environmental impacts. Table 1 shows the evaluation criteria used by the eight labelling schemes.

2.1. Evaluation criteria for health impact categories

The objective is to present the influence of the product on human health. The user of an EPD should be able to compare the influence of different products on human health and use this information as a criterion for selection. The influence of the product on human health is presented as health impacts by five different outcomes, comparable to the environmental impacts.

The following outcomes are selected for presentation of the influence of a product on the indoor environment:

- Negative indoor air quality potential.
- Carcinogenic potential.
- Mutagenic and reprotoxic potential.
- Allergenic potential.
- General toxicological potential.

Time for evaluation: day 3 and day 7 after start of the experiment.

2.1.1. Negative indoor air quality potential

Negative indoor air quality potential is a new concept defined for the purpose of this study. The emission of TVOC and the emission of formaldehyde/acetaldehyde/propionaldehyde/butyr aldehydes as individual compounds are added to a joint concept called "negative indoor air quality potential". Among the existing schemes the following concepts are used: VOC, TVOC, SVOC, formaldehyde, sum of formaldehyde and acetaldehyde, total aldehyde, 4-phenylcyclohexane, saturated n-aldehydes, alkylaromates, and bicyclical terpenes. All of these chemicals are included in the indoor air quality potential.

2.1.2. Carcinogenic potential

Carcinogenic potential is widely used as a health effect category (M1, AgBB, Blue Angel, Natureplus). There is much focus on carcinogenic compounds, not only among the labelling schemes. The Californian Proposition 65 scheme also pushes the development towards against products without carcinogenic compounds (Cal/EPA, 2012). The carcinogenic potential covers all compounds classified in categories 1, 2, and 3 by the EU and the International Agency for Research on Cancer (IARC). The potential is calculated as the sum of concentrations of individually identified and qualified compounds in each category.

2.1.3. Mutagenic and reprotoxic potential

Mutagenic and reprotoxic potential is already used by the labelling systems Natureplus and Blue Angel. The existence of corresponding systems for classification of mutagenic and reproduction toxicity effects similar to the systems mentioned for carcinogenic compounds, facilitates the use of mutagenic and reprotoxic potential as an outcome. The potential is calculated as the sum of concentrations of individually identified and qualified compounds in each category.

2.1.4. Allergenic potential

Allergenic potential is an important outcome. The incidence of people suffering from asthma or allergies is increasing, and people who are affected want to know whether a product emits allergenic substances. The allergenic potential is already used by Natureplus. Chemicals that have been proven to be allergenic have been labelled with *risk phrase R42: May cause sensitisation by inhalation*, and *R43: May cause sensitisation by skin contact* in the EU until recently. Due to the introduction of CLP/GHS this will hereafter be labelled *Skin Sens 1; H317* and *Resp, Sens 1; H334*. This system could be used for selecting substances that should be included in the allergenic