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METHODS FOR ENVIRONMENTAL ASSESSMENT OF BUILDING MATERIALS

A building is an artificial environment designed and built to meet user need and material is the most basic product of building production. Building products so directly or indirectly interact with the environment. The main environmental evaluation methods as well as the simple example of environmental assessment of selected building material are presented in this paper.

Introduction. The design of environmental friendly buildings is a complex task due to the large number of factors that must be addressed and the lack of knowledge about the effects of interactions among the various environmental factors and the human and environmental responses to them. Since the building material is the most basic factor of building production, the environmental assessment of building products should be a factor if importance in building environmental auditing [1]. Environmental assessment of building materials became a area of interest of many specialists in civil engineering [2,3,4]. The basic aim of this research area is to make architects, producers and users conscious of the interaction between building products and environment during product life cycle as well as to make it possible to select building products in an easy and correct fashion and so produce healthy buildings.

Environmental assessments may be performed at different levels with varying degrees of precision, and with special attention directed to different environmental effects, depending on the particular purpose and scope of the study. However, when performing an environmental assessment, there are four main steps that must always be performed: a precise description of the system that is studied, preparation of an inventory of all environmental aspects caused by activity, classification of the environmental aspects according to the environmental effects they cause or contribute to and quantification of their contributions and finally the evaluation of the environmental performance of the alternatives under study.

This paper is aimed to some environmental evaluation methods presentation as well as the simple example of environmental assessment of selected building material illustration.

Evaluation methods. In order to determine the interaction between the building products and environment it is necessary to understand the environmental effects of product throughout the product life cycle. Life cycle assessment method is one of the most used methods for environmental evaluation of building materials, which include the existing and potential environmental impacts evaluation of material within their whole life cycle. This life cycle includes processes such as raw material extraction, production of the building product including packaging and distribution, application of the building product to building, usage and at the very end recycle or disposal [2].

For the first evaluation step in LCA analysis, the building product to be evaluated must be defined. This definition consists of the general information of the building product (name and type, physical and chemical definition, etc.), information of life cycle processes, type of used data, function unit, and description of evaluation methodology.

In the second step the inventory is realised. That means that all environmental aspects - inputs and outputs related to the building material life cycle must be listed. The inventory data for a particular emission may be expressed mostly in qualitative terms. The inventory should also register the consumption of all non-renewable resources, as well as the most important of the renewable resources.

In the third step there are all environmental aspects and resource consumption listed in the inventory categorised and their expected contributions quantified. Traditionally, inventories have divided emissions according to the environmental compartment they released into: air, water and the soil. Recent developments in environmental assessment suggest that a cross-media approach should be applied; classifying emissions into environmental categories according to the environmental effects types they may contribute to [5]. The purpose of this approach is to focus on the potential problems that may be caused by the emissions.

There are many methods used within LCA, different from the categories the environmental aspects are classified in, or the ways of effects quantification they contributed to. The general approach is based on the CML method [6], which the environmental aspects divided in the categories listed in the table 1.

Table 1

Environmental categories considered in the classification step subdivided according to their scale of activity

Scale	Environmental category
Global	Greenhouse effect
	Stratospheric ozone depletion
Regional	Acidification
	Eutrophication
	Photochemical ozone formation (summer smog, winter smog)
	Chronic toxicity
Local	Acute toxicity
	Area degradation (noise, odour, risk)
	Physical disturbances

The expected contributions of characterized environmental aspects must be quantified by their own model for contributions computing. For the categories that are caused by chemical emissions, the model consists of all the main compounds that are thought to contribute to the environmental effect, together with a conversion factor for computation of the specific potential contribution of the compound. The compound the most contributing to the environmental effect is usually defined as a unit equivalent and the total contribution of all emissions is expressed in these units. For example, for each of the compounds in the inventory contributing to the global warming effect, their size is converted into the common unit of kg CO_2 equivalents end expressed as global warming potential (GWP) by multiplication with the conversion factor given for that compound:

$$\text{GWP (kg } CO_2 \text{ eqv.)} = \text{airborne emission (kg) x conversion factor}$$

The unit equivalents for selected environmental categories are illustrated in table 2.

Table 2

Unit equivalents for some environmental effects potentials [7]

Environmental category	Unit equivalent
Global warming potential (GWP)	CO_2
Ozone depletion potential (ODP)	CFC-11
Acidification potential (AP)	SO_2
Eutrophication potential (NP)	NO_3^-
Photochemical ozone creation potential (POCP)	C_2H_4

Environmental category for toxicity includes contributions of thousands chemical compounds to toxicity affecting living organism or ecosystem. Therefore, potential contribution to acute or chronic toxicity is much more difficult to quantify and to aggregate than contribution to any other effect types. The often use approach is based on the specific calculation of human toxicity (combined score for air, water and soil) and ecotoxicity (aquatic and terrestrial) [5]. The new categories related to toxicity such as heavy metals, pesticides and carcinogens are also considered in environmental assessment now. Area degradation and physical disturbances can be expressed in a functional unit of km^2 of affected area. The categories as solid waste or source exhaustion may be also considered. The result of the third step of environmental assessment is the building material environmental profile creation. Environmental profile presents the potential contribution of building material to all of the environmental effect types within the whole life cycle.

The final step of environmental assessment is the evaluation including normalization and weighting. Whereas the environmental assessment up to this final step has been performed on an objective and scientific basis, the evaluation as a comparison of environmental profiles of the different materials or alternatives is the part of the environmental assessment, where the subjective decisions are gathered and isolated. So the evaluation should not be considered as the final step but rather an integrated step, giving feedback to the initial steps, e.g. suggesting amendments to the alternatives that are compared.

The environmental assessment of selected building material. Burnt brick was selected as a building material for environmental assessment. The primary data from East Slovak producer of brick as well as secondary data were used in environmental assessment. The life cycle of brick consist of several phases: raw material (clay) extraction near the brick plant, brick production – brick formation, drying and burning (baking), transportation as an integral step, application of brick in building processes and recycle or disposal. Recycle of brick is a way for the brick material reusing, e.g. as brick-nogging, broken brick concrete or molded brick [8].

The oversimplified approach was chosen in environmental evaluation and the production phase was selected for assessment of brick because of absence of quantitative data in the other phases. The production phase was suggested to have a significant impact on environment. The function unit was stated of cubic meter of brick what represents 175 pieces of brick.

The main environmental aspects related to the production phase were identified – table 3 and expressed to function unit – cubic meter of brick. The mass concentration of environmental aspects (carbon monoxide, carbon dioxide, nitrogen oxides, sulfur dioxide and particulate matter) were measured by emission measurements.

Table 3

The inventory of main environmental aspects

Emission	Mass concentration [kg/m^3 of brick]
sulfur dioxide	0,264
nitrogen oxides	0,462
carbon dioxide	342
carbon monoxide	0,038
particulate matter	6,897
volatile organic compounds	0,09*
polycyclic aromatic hydrocarbons	0,0008*

**secondary data from literature*

The CML method was used for categorization and quantification of environmental aspects. Emissions of sulfur dioxide contribute to a lowering of the pH in some compartment of the environment causing acidification in regional scale. The SO_2 emissions contribute also to the winter smog formation. The nitrogen oxides are contributed to several environmental effects in regional scale: eutrophication, acidification and global warming. The carbon monoxide and carbon dioxide emissions belong to the main contributors of greenhouse effect resulting in global warming. Particulate matter emissions contribute to the winter smog formation. The organic compounds (volatile organic compounds and polycyclic aromatic hydrocarbons) caused human and ecotoxicity and may be also classified as carcinogens.

Environmental aspects were quantified by unit equivalents and expressed as partial potentials. The embodied energy for brick production was calculated. The value of 6,26 GJ per cubic meter of brick was stated. The calculation was performed also to mass unit of brick and the embodied energy related to 1 kg of brick was 4 MJ. This value is comparable to the results of the others authors [9]. The environmental profile of burnt brick was made from obtained results – table 4.

Table 4

Environmental profile of burnt brick

Potentials of environmental effects	Unit	Value
Global warming potential GWP	[kg CO_2 eqiv.]	342
Acidification potential AP	[kg SO_2 eqiv.]	0,2937
Eutrophication potential NP	[kg NO_3^- eqiv.]	0,6237
Winter smog potential	[kg SO_2 eqiv.]	0,17
Carcinogenesis	[kg PAH eqiv.]	0,0008
Embodied energy	[MJ/kg of brick]	4

The most important environmental effect in production phase of burnt brick resulted from the environmental assessment are the carbon oxides emissions. The global warming potential has reached the much higher values than the other potentials evaluated in study. There is need to emphasize, that this paper presented only the oversimplified approach to the environmental assessment of selected building material because of absence of enough data from producer and the absolute numbers resulting from study are for illustration. For evaluation within LCA methods it is necessary to evaluate two or more products or alternatives and at the end of evaluation to choice the better one.

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IDENTIFICATION OF THE NOISE SOURCES IN A STEEL RAILWAY BRIDGE

This paper presents the results of a noise study in the areas surrounding a railway line and a bridge, in a large municipal agglomeration. Sound characteristics were determined in the one-third octave bands and narrow frequency bands, and bridge vibration studies were carried out. The relationships between the vibrations of some elements of the structure and the acoustic pressure in its environment were revealed by applying a coherence function. The sources of excessive noise emissions to the surrounding environment were identified, and solutions for modernizing the railway infrastructure of the region were proposed.

Introduction. Moving railway transport vehicles are sources of noise, and determine the acoustic climate around railway lines. Bridge structures can also act as sources of noise when railway vehicles travel over them [1, 2]. In addition to the aerodynamic noise of travelling vehicles, and the sounds emitted directly by wheels and rails when they pass over steel bridges, the transverse vibrations of structural sheets can emit aerial sounds that are an environmental nuisance [3]. 'Material' sounds of various types (e.g. longitudinal, transverse or bending waves) can be produced by numerous mechanisms, such as periodic or periodically changeable influences that alter the position or force constants (the rolling process). Steel provides low internal attenuation, and structures made of steel can easily be subject to poorly damped free vibrations and/or resonance of high amplitudes. In particular, in structures with large-surfaced elements, the induced transverse vibrations can lead to large emissions of aerial sound that are received by the human ear as noise. This noise, which is dominated by low-range frequencies due to its long wavelengths, spreads across large distances as it is only slightly attenuated by obstacles, and easily penetrates into residences. The unpleasant buzzing characteristics of this noise make it particularly vexing to the human ear, both outside and inside residential dwellings.

Characteristics of railway lines and bridges. This study investigated a railway line and bridge located within an intensively developed industrial area. There were multi-family residential houses (Figs. 1, 2) located within its immediate neighbourhood (i.e. 28 m from the railway track). The railway track was jointless, and ran along an embankment in the form of a horizontal bend with a radius (R) of 250 m. The technical condition of the track was unsatisfactory (i.e. its horizontal curvature deviated from the correct theoretical shape and was, in fact, a broken line consisting of several arc sections).

Fig. 1. Top view of the railway bridge and multi-family residential house