Editorial

iMedPub Journals
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Environmental Toxicology Studies Journal

2017
Vol.1 No.1:2

Emphasizing the Importance of Life Cycle Assessment and Ecotoxicological Studies of Construction Materials

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Received date: October 10, 2017; **Accepted date:** October 25, 2017; **Published date:** November 10, 2017

Citation: Flores-Colen I, Silvestre JD (2017) Emphasizing the Importance of Life Cycle Assessment and Ecotoxicological Studies of Construction Materials. Environ Toxicol Stud J. Vol: 01 No 1: 02.

Introduction

The construction industry is an unsustainable sector because it reports for around 30% of CO_2 emissions and consumes 50% more raw materials than any other economic sector [1]. Although EUROSTAT [2] data (1990-2012) reveals a 38% reduction in CO_2 emissions, it is critical to continuously decrease the production and consumption of cement and natural aggregates to achieve the sustainability in construction. The production of construction materials is in general associated to significant environmental impacts and waste generation, but leads also in some cases to a high degree of toxicity to human health and to the environment [3]. These risks can be higher, but usually not even accessed, in the case of non-traditional innovative construction materials.

The Life Cycle Assessment (LCA) of products is required to estimate the environmental, energy and economic impacts throughout their service life, from the extraction of raw materials to the final disposal [4]. Since the sixties, studies and several methods have been put into practice with the aim of optimizing the products, in order to make them more sustainable and less harmful to the environment. It was only in 1990 that SETAC (Society of Environmental Toxicology and Chemistry) established a standardized environmental LCA methodology. The complexity of the LCA approach requires a pre-defined procedure with the objective of making it as accurate as possible. The methodology is divided into four main phases: (1) defining the purpose and scope of the study, (2) inventory analysis, i.e., compilation of all inputs and outputs, (3) evaluation of the impacts of inputs and outputs in the system and (4) interpretation [5].

The toxic effects caused by natural or artificial elements in living organisms are studied by Ecotoxicology. This branch of science evaluates the potential environmental risk associated with the materials to be incorporated in the construction, even without the need of using LCA. The potential ecotoxicity of materials/products is evaluated by using leaching tests, chemical analyzes and (eco) toxicity tests. There is a lack of harmonization among the scientific community and the related regulation is still scarce [3]. Technical Committee 350 of the European Committee for Standardization [6] is developing a new standard to assess the environmental impact of construction materials at European level, i.e. by introducing new categories, in particular ecotoxicology.

Researchers from CERIS-IST (CERIS - Civil Engineering Research and Innovation for Sustainability, Instituto Superior Tecnico) in the last few years, have completed LCA studies for construction materials, such as: recycled concrete aggregates [7-10], cork-based materials [11-13], external wall' assemblies [4,14], and insulation materials [15], using national site specific data. A previous study [16] demonstrated that the application of the latest European standards on the environmental assessment of waste streams can be an important source of data for the end-of-life decision making of building materials, especially to determine whether the minimization of waste streams, maximizing reuse or recycling operations, or increasing recycled content maximizes the environmental performance of the entire life cycle (from cradle to grave).

In addition, LCA of innovative building materials has also been developed at CERIS-IST, focusing on improving the use of existing information to: evaluate the influence of uncertainty on service life on the environmental LCA results of coatings [17]; and select the best LCA data sources to be applied in each national context [18].

An expedient methodology for the ecotoxicological potential evaluation of raw and construction materials was proposed [3] to allow for the introduction of ecotoxicological analysis in LCA studies. An ecotoxicological characterization of raw materials and concrete samples was performed based on toxicity tests, and concluded that the micro crustacean Daphnia magna showed the highest levels of sensitivity in all samples tested. The results also suggested that the yeast (*Saccharomyces cerevisiae*) may be a relatively good replacement for preliminary studies, before more complex and expensive tests with ecologically more relevant animals.

The concept of the cost associated with a product's life cycle was introduced between 1980 and 1990, considering the internal and external costs and their allocation to all stakeholders [19]. Thus, the evaluation of the Economic LCA (or Life-Cycle Cost) of a product is extremely important today, as an increasing measurement and control of expenses incurred in the construction sector is necessary, and contributes to a more sustainable construction. The economic studies are usually based on the method recommended in ISO 15686-5 international standard [20], following most of the principles already included in the EN 15643-4 European standard [21].

Several Economic Life Cycle Assessment were also developed at CERIS-IST based on Cradle to Cradle LCA studies, considering the main life-cycle stages (raw material acquisition, production, transportation and on-site installation, maintenance, demolition and final disposal), and including economic [22,23] and energy savings [19,24].

Life Cycle Assessment and Ecotoxicological studies are useful tools for the design, development and application of construction materials, reducing their environmental, energy, economic and ecotoxicity impacts and thus contributing to the construction sustainability.

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