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Life Cycle Assessment of Concrete Blocks Masonry: Processes Contribution Analysis

Cristiane Bueno
Architecture and Urbanism Institute, University of Sao Paulo, São Paulo 05508-030, Brazil

Abstract: The purpose of this paper is to identify the processes with the highest contribution to potential environmental impacts in the life cycle of the masonry of concrete blocks by evaluating their main emissions contributing to impact categories and identifying hotspots for environmental improvements. The research is based on the Life Cycle Assessment (LCA) study of non-load-bearing masonry of concrete blocks performed by the authors. The processes those have demonstrated higher contribution to environmental impacts were identified in the Life Cycle Impact Assessment (LCIA) phase and a detailed analysis was carried out on the main substances derived from these processes. The highest potential impacts in the life cycle of the concrete blocks masonry can be attributed mainly to emissions coming from the production of Portland cement, which explains the peak of impact potential on the blocks production stage, but also the significant impact potential in the use of the blocks for masonry construction, due to the use of cement mortar. The results of this LCA study are part of a major research on the comparative analysis of different typologies of non-load-bearing external walls, which aims to contribute to the creation of a life cycle database of major building systems, to be used by the environmental certification systems of buildings.

Key words: Life cycle assessment, masonry of concrete blocks, contribution analysis, sensitivity analysis.

1. Introduction

The use of electric power has become essential for cooling purposes inside buildings in regions where outdoor temperatures in summer are considerably high and the use of insulating materials is not popular due to the fact that such materials' installation is expensive and requires skilled labour. In these regions, mostly in developing countries, the development of simply handled concrete blocks with high thermal insulation properties is a necessity [1].

According to [2], considerable amount of energy is spent in the manufacturing processes and transportation of various building materials and the conservation of energy becomes important in the context of limiting of green house gases emission into the atmosphere and reducing costs of materials. It has been shown that total embodied energy of load bearing masonry buildings can be reduced by 50% when energy efficient/alternative building materials are used [2].

Intensive literature survey and hearing to the institutes concerned have been deliberately conducted by [3] to collect relevant data to concrete materials, other materials involved, construction, demolition, and disposal and recycling and environmental impact caused by the construction of concrete was considered as a performance parameter in order to confirm the applicability of these inventory data to environmental performance evaluation of concrete structures.

State of the art life cycle inventory (LCI) models are typically used to relate resource use and emissions to manufacturing and use of a certain product [4]. In some cases, it is, however, desirable to make use of the LCI model for other types of environmental assessments. Although ISO 14031 gives guidelines for environmental performance evaluation, there is limited experience of applying the standard in the area of benchmarking and

Corresponding author: Cristiane Bueno, professor, research fields: green building and building technology.

external rating, especially when limitations of data quality are considered. There is no sharp limit when the quality of emission factors is high enough to make it possible to compare, since quality is a qualitative conception in itself [5].

The purpose of the present paper is to identify the processes with the highest contribution to potential environmental impacts in the life cycle of the masonry of concrete blocks by evaluating their main emissions contributing to impact categories and identifying hotspots for environmental improvements.

2. Methods

The research is based on the Life Cycle Assessment (LCA) study of non-load-bearing masonry of concrete blocks performed by the authors. The processes those have demonstrated higher contribution to environmental impacts were identified in the Life Cycle Impact Assessment (LCIA) phase and a detailed analysis was carried out on the main substances derived from these processes.

The methodology will be guided by ISO 14044 [6] through the application of the script proposed by ILCD Handbook [7].

2.1 Objective and Scope

The research has considered buildings with independent structure, where all the loads are discharged in such independent structural elements and the wall analyzed had only a sealing function.

Thus, the functional unit addressed in this research was of 1m² of non-structural external wall which provides thermal and acoustic performance as required by relevant Brazilian standards for the application in the city of Sao Paulo, for a period of 40 years.

The hollow structural block used in the masonry evaluated in this research has dimensions of 14x19x39cm with characteristic resistance to compression of 6 MPa. The block will be considered sitting in its smaller dimension, giving the wall (without coating), the thickness of 14cm, using laying mortar thickness of 1.0cm. The concrete block is 14cm thick with external and internal mortar coating thickness of 2cm.

The wall was considered as not receiving any painting on its external and internal faces.

Based on these statements, the reference flow for the functional unit of 1m² of non-load-bearing wall consisted of 16.67 concrete blocks, 0.0126m³ of sitting mortar and 0,04m³ of mortar coating.

Therefore, the manufacture of 16.67 concrete blocks requires 29.173kg of Portland cement, 108.355kg of sand, 50.01kg of gravel (basalt) and 12.753kg of water. For the structural masonry of concrete blocks the total amount of inputs for the mortar production (coating and settlement) for the functional unit of 1m² (0.0526m³) is 5.786kg of Portland cement, 10.783kg hydrated lime, 65.75kg of sand and 18.41kg of water.

The cut-off criteria allowed the exclusion of the elementary flows if their relevance in the final results was below 0.1%.

The product system studied in this LCA is shown in **Fig. 1**.

2.2 Life Cycle Inventory Analysis (LCI)

This study was based on data from Ecoinvent 2.01 Database [8].

For the collection of inventory data on transportation processes regarding the distribution of blocks, a 100km-distance was considered for comparison purposes. Regarding the transport for disposal of demolition rubbish, a 10km-distance was considered.

2.3 Life Cycle Impact Assessment (LCIA)

The Life Cycle Impact Assessment (LCIA) was carried out by using the ReCiPe 2008 methodology [9], applying the midpoint impact categories. The ReCiPe methodology was chosen due to its regional scope of application directed to Europe and not to specific countries.

This paper did not apply the normalization and weighting of results.

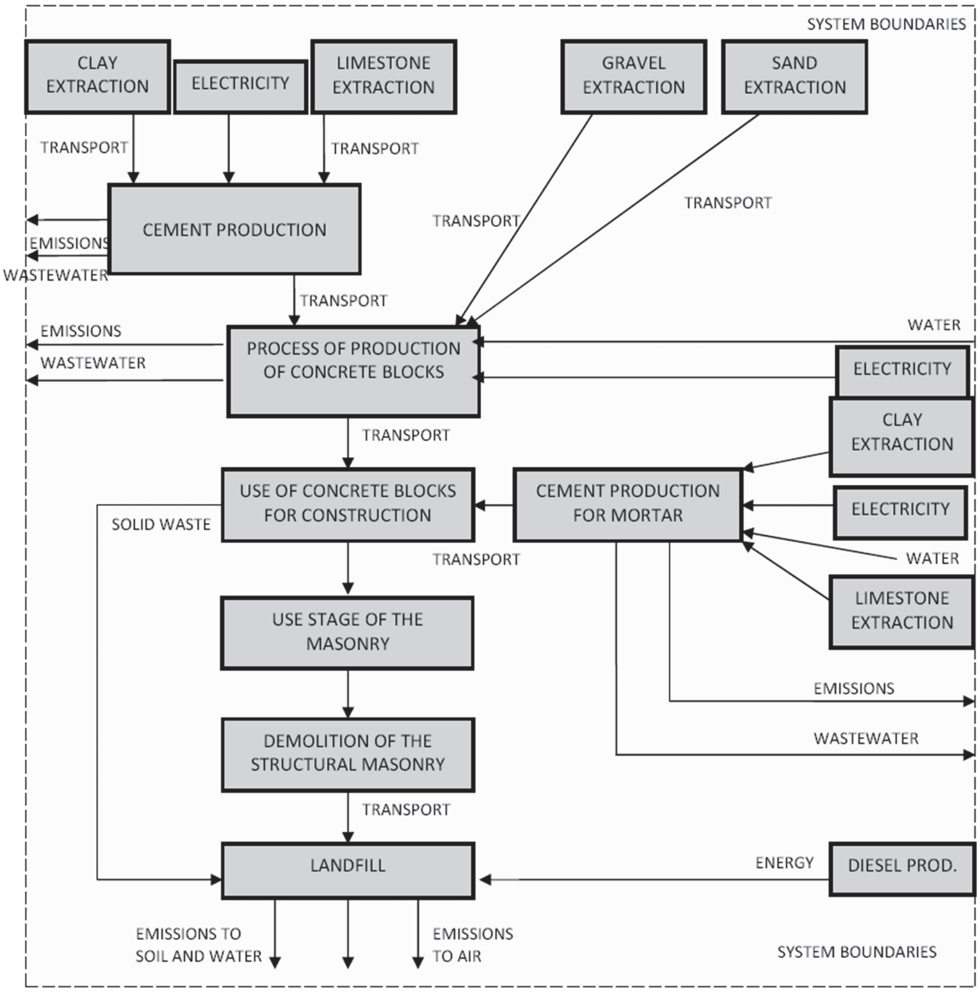


Fig. 1 System Boundaries of Concrete Blocks Masonry and system boundaries.

3. Results and Interpretation

Fig. 2 shows the LCIA results at midpoint, however the analysis of the results requires the observation of each category of impact in isolation, since the most impacting processes may vary for each category. Thus a careful analysis is necessary to ensure the transparency of the study.

Concerning Agricultural Land Occupation (Fig. 3), the cement mortar production has shown a higher consumption to potential environmental impacts. On the other hand, the concrete block production has shown higher potential impact to the category Urban Land Occupation. Such different results can lead to the conclusion that, the impacts on Agricultural Land Occupation are due to the extraction of clay and limestone for mortar production, and its consequent mining sites.

Regarding the Urban Land Occupation (Fig. 3) results pointing out to the concrete block production (including cement production) as the most contributing process, it can be explained by the dimensions of the cement, concrete and blocks plants, all located in the urban area.

The same can be observed for the category Natural Land Transformation (Fig. 4), where the most contributing processes are the concrete block (and cement) and cement mortar production. Such result is due to the mining for extraction of sand, limestone, clay and gravel for cement and concrete production.

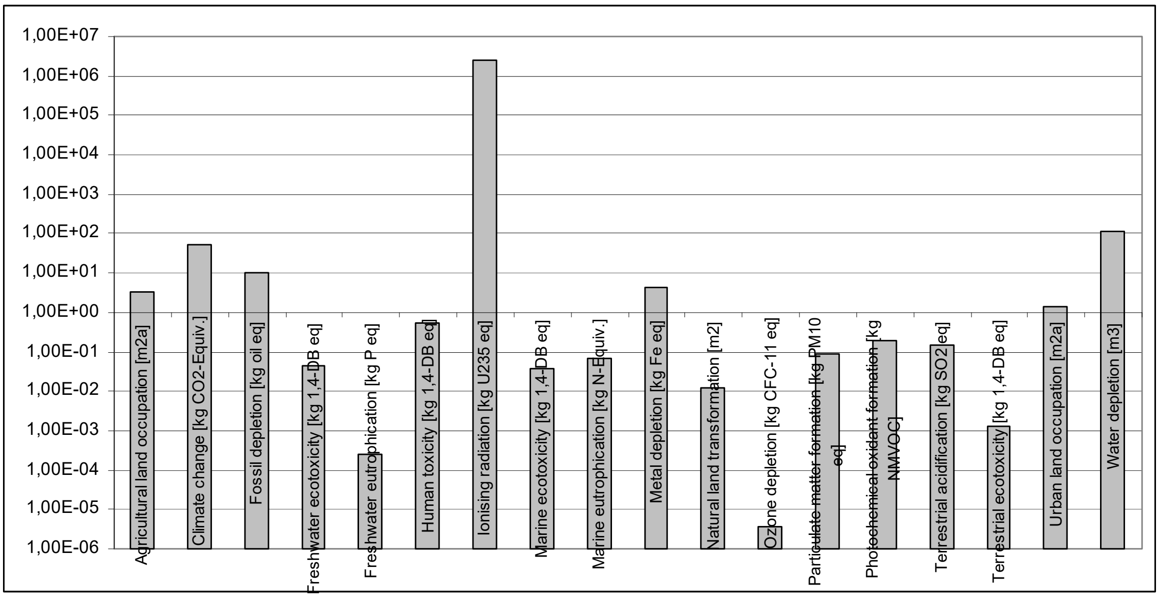


Fig. 2 LCIA results at midpoint.

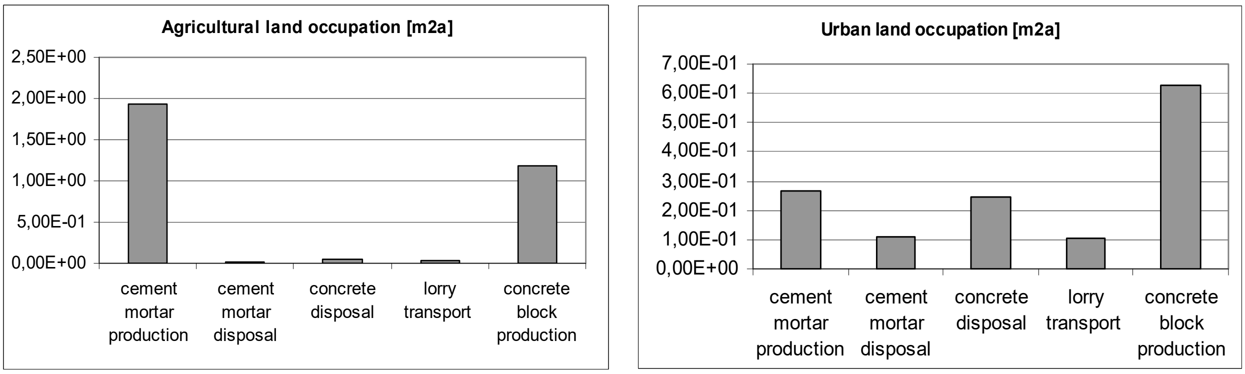


Fig. 3 Most contributing processes in the categories Agricultural and Urban Land Occupation.

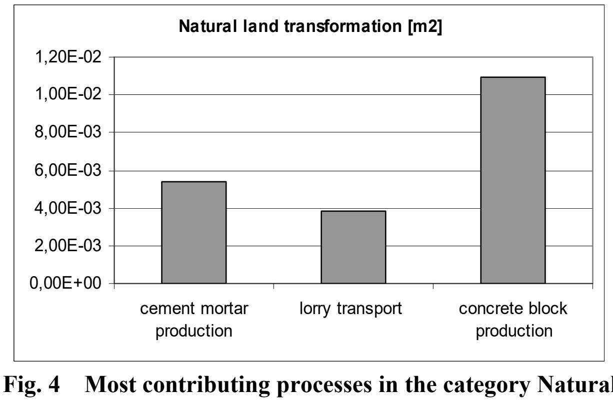


Fig. 4 Most contributing processes in the category Natural Land Transformation.

Fig. 5 shows the impact assessment results for the categories Climate Change and Ozone Depletion. For these two categories a diverse scenario was also found where concrete blocks and mortar production have shown larger contributions to climate change, due to the emissions from the cement production process, while transportation has presented the highest contribution to Ozone Depletions category, due to the diesel burning emissions. However, for this last impact category, it's worth to note that processes which comprise cement production have also shown considerable contributions.

Regarding the consumption of resources two very different scenarios can be observed for Fossil and Metal Depletion (Fig. 6). It can be noted a substantially large consumption of fossil resources in most of the main process, especially those involving cement production and fossil fuels consumption. In the other hand, concerning Metal depletion, the highest consumption potential is concentrated in the process of production of concrete blocks, mostly due to the use of natural aggregate (gravel) in concrete.

For the categories Freshwater and Marine Ecotoxicity and Freshwater Eutrophication (Fig. 7 and 8) the impact potential profiles for processes in the life cycle of concrete masonry are very similar, showing the larger contributions coming from the concrete blocks production process, followed by transportation and cement mortar production. However, the impact potential profile is quite different regarding Marine Eutrophication (Fig. 8), where the most impacting process has shown to be the lorry transportation, followed by concrete blocks and mortar production.

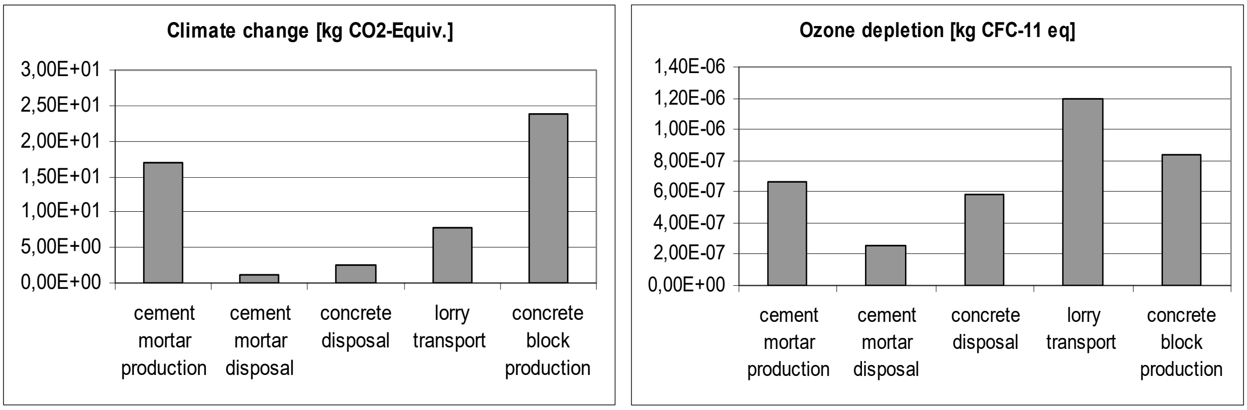


Fig. 5 Most contributing processes in the categories Climate Change and Ozone Depletion.

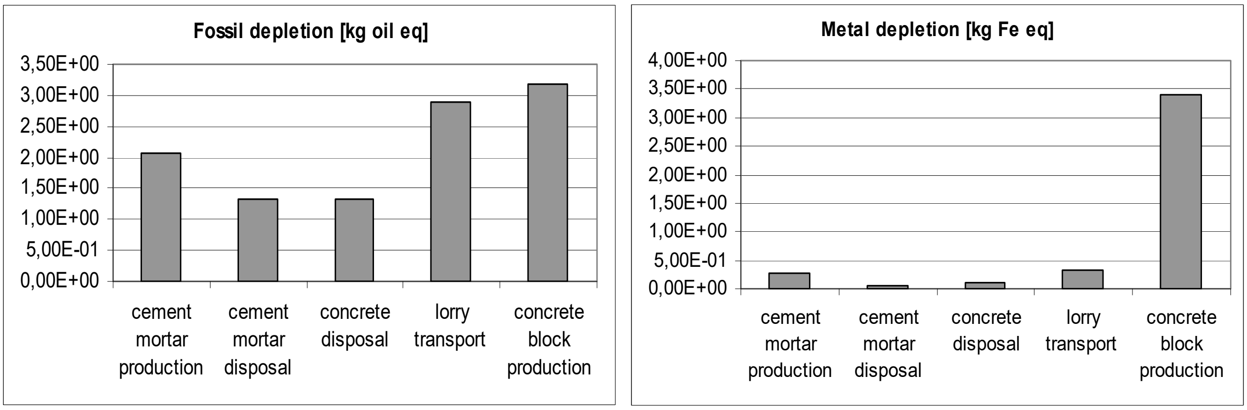


Fig. 6 Most contributing processes in the categories Fossil and Metal Depletion.

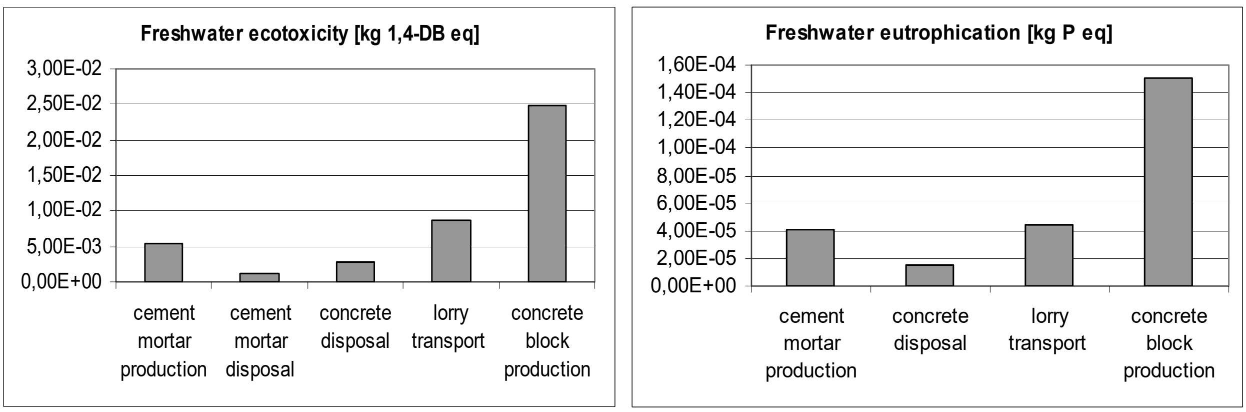


Fig. 7 Most contributing processes in the categories Freshwater Ecotoxicity and Eutrophication.

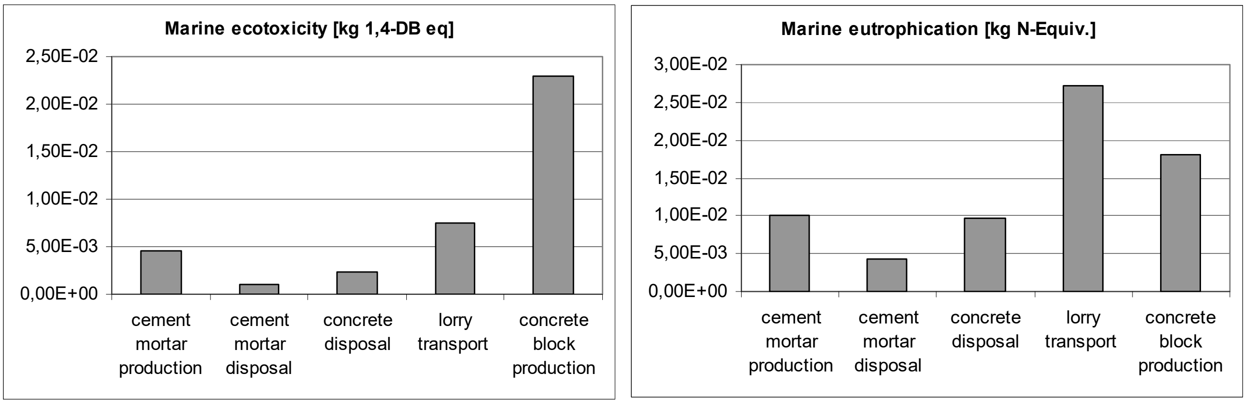


Fig. 8 Most contributing processes in the categories Marine Ecotoxicity and Eutrophication.

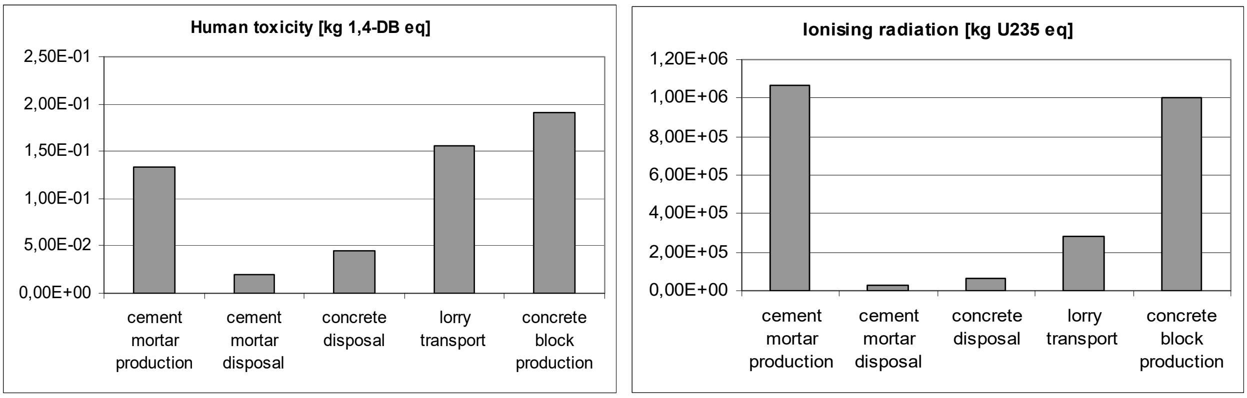


Fig. 9 Most contributing processes in the categories Human Toxicity and Ionizing Radiation.

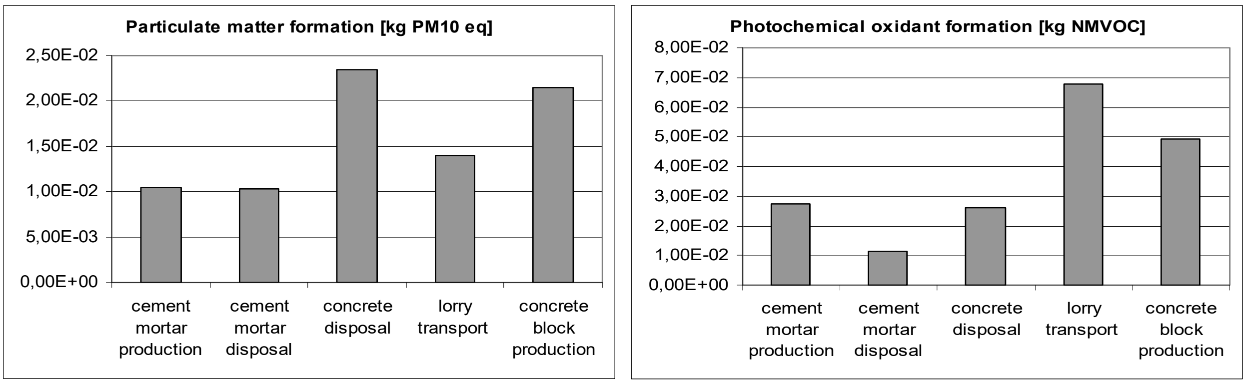
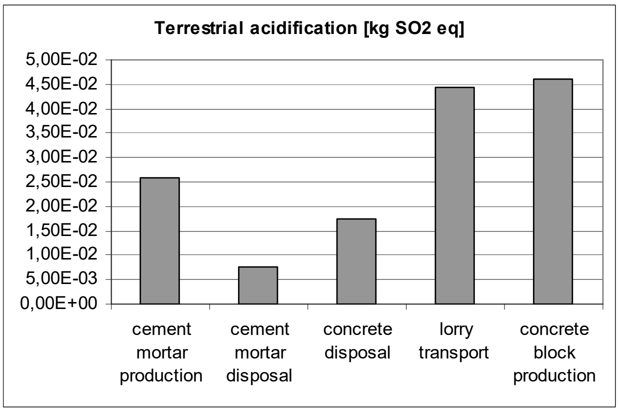


Fig. 10 Most contributing processes in the categories Particulate Matter and Photochemical Oxidant Formation.

The Human Toxicity impact category has shown the same typical profile of some of the categories discussed previously, regarding freshwater impacts but for Ionizing Radiation, differently the highest impact magnitude was found in the cement mortar production process (Fig. 9).

Regarding Particulate Matter Formation, for the first time in this study, the most prominent impact potential is located in the concrete disposal category while the lorry transportation process is responsible for the most impacting emissions to Photochemical Oxidant Formation, as shown in Fig. 10.

Regarding impacts to the soil, Fig. 11 shows the most impacting processes in the categories Terrestrial Acidification and Terrestrial Ecotoxicity. For both categories the most contributing processes are lorry



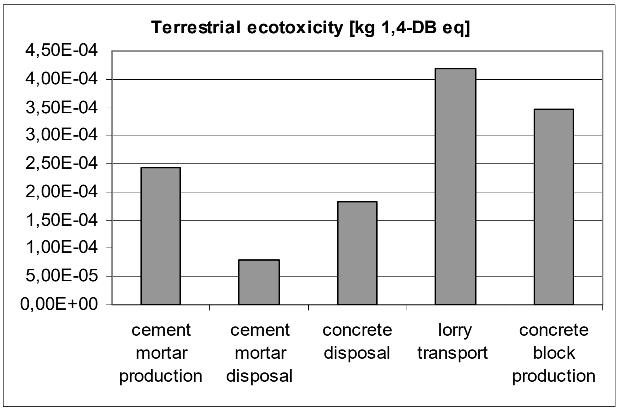


Fig. 11 Most contributing processes in the categories Terrestrial Acidification and Ecotoxicity.

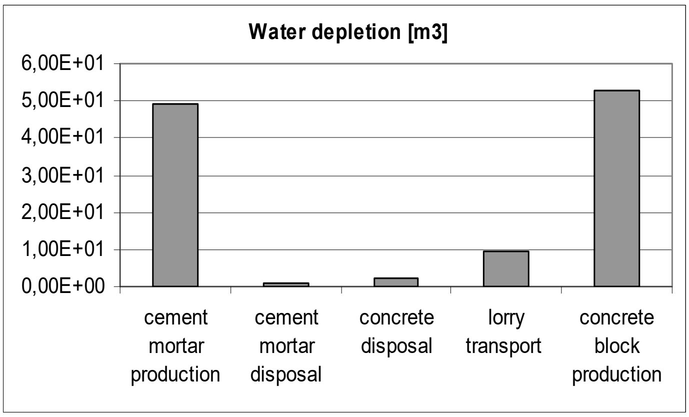


Fig. 12 Most contributing processes in the category Water Depletion.

transportation and concrete block production, however, transportantion is more impacting for Ecotoxicity while block production is more impacting for acidification.

Finally, the water depletion category has shown its potential impacts concentrated mostly in the cement mortar and concrete blocks production, what lead to the conclusion that the cement production is the most water depleting process.

4. Conclusion and Recommendations

The highest potential impacts in the life cycle of the concrete blocks masonry can be attributed mainly to emissions coming from the cement mortar and concrete blocks production processes, for most of the impact categories, leading to the conclusion that such impacting emissions are actually located in the production of Portland cement which explains the peak of impact potential on the blocks production stage, but also the significant impact potential in the production of cement mortar.

Also for some other categories as Ozone Depletion, Marine Eutrophication, Photochemical Oxidant Formation and Terrestrial Ecotoxicity, the most impacting emissions were coming from the lorry transportation process, especially related to the diesel burning emissions in the truck engine.

Therefore it is possible to conclude by this Life Cycle Assessment study that the hotspots for environmental improvement in the lifecycle of the Masonry of Concrete Blocks are most specifically located in the process of production of cement, and fuels burning during transportation.

Other impacts which could be indirectly identified through the analysis of the categories Agricultural Land Occupation and Natural Land Transformation are those coming from the mining activities. Such raw materials extraction are not directly assessed by the LCIA methodology but were clearly observed in the discussion of the results.

The results of this LCA study are part of a major research on the comparative analysis of different typologies of non-load-bearing external walls, which aims to contribute to the creation of a life cycle database of major building systems, to be used by the environmental certification systems of buildings. Further research point out to the sensitivity analysis of the results to the use of secondary data or primary data and also the application of different LCIA methodologies will be performed in order to identify which impact categories are the most significant in the assessment of traditional wall systems and which need thus further specific development.

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