ATTI

XIV Convegno della rete Italiana LCA
IX Convegno dell'Associazione Rete Italiana LCA

La sostenibilità della LCA tra sfide globali e competitività delle organizzazioni

Cortina d'Ampezzo
9-11 dicembre 2020

A cura di Erika Mancuso, Sara Corrado, Arianna Dominici Loprieno, Laura Cutaia

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Rete Italiana LCA

UNIVERSITÀ DEGLI STUDI DI PADOVA

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Andrea Pontrandolfo, *Università degli Studi di Bari "Aldo Moro"*

10 dicembre 2020

9.15-10.30

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Chair: Marina Mistretta, Giuseppe Tassielli

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Giovanni Dolci, *Politecnico di Milano*

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Environmental impacts evaluation of a ceramic industry processes through integration of Life Cycle Assessment and Risk Assessment

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How can Life Cycle Assessment contribute to circular economy transition: hints from sustainability transition research

Monia Niero, *Aalborg University Copenhagen*

10.30-12.15

SESSIONE III

Sostenibilità in Edilizia

Chair: Monica Lavagna, Vito D'Incognito

Environmental impacts evaluation of a ceramic industry processes through integration of Life Cycle Assessment and Risk Assessment

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Abstract

This study aims to assess the impacts of three waste management scenarios, two representing internal recycling and one landfill disposal of ceramic powders generated by tiles edge-grinding in ceramic tile production processes. In eight out of nine environmental categories examined through Life Cycle Assessment (LCA) methodology, results show that the two recycling scenarios have impacts at least one order of magnitude smaller than the disposal scenario, confirming the effectiveness of the circular economy approach. An additional Risk Assessment (RA) analysis is carried out through WinDimula 3.0 model applied to recycling scenarios to measure and compare the dispersed powder impacts on human health. The combined use of site-generic (LCA) and site-specific (RA) assessment methods allows analysed system knowledge to increase towards a more complete and holistic evaluation of critical environmental issues.

1. Introduction

In recent years Italian industries are showing a growing interest towards the use of Life Cycle Assessment (LCA) methodology as a decision support tool to improve the environmental performance of their own production processes. This trend has been induced by increasingly pressing market needs due to a greater sensitivity among consumers over environmental issues. In addition, the European Commission's Circular Economy Package (EC, 2015), supported by a set of measures promoted at national and regional level, has involved many manufacturers of different industrial sectors in a virtuous process towards innovation and sustainable production, also aligning their waste management to the principles of reduction, reuse, recycling and recovery.

The Italian ceramic industry is one of the leading sectors of made in Italy and is highly aware of environmental sustainability issues. In 2016, the Environmental Product Declaration (EPD) for Italian ceramic tiles was developed with the aim of providing clear and comparable information regarding the environmental performance of this industry (Confindustria Ceramica, 2016). In 2019, Confindustria Ceramica clarified the sector's position with respect to the 17 new UN Sustainable Development Goals (SDGs) by publishing a Report devoted specifically to the characteristics of the Italian ceramic industry (Ceramica.info, 2019). In the past years, several LCA studies about ceramic industry processes have been carried out. Most of them consider the impacts associated with the entire life cycle ("cradle-to-grave" approach), focusing on either a specific type of ceramic tile (Ibáñez-Forés et al., 2011; Pini et al., 2014), or the comparison between different products (Nicoletti et al., 2002; Almeida et al., 2016; Ros-Dosdá et al., 2018) or the assessment of environmental, economic and social sustainability of the whole sector (Blundo et al., 2019). In almost all these studies, the life cycle phase with the highest environmental burden is the tile's manufacturing, in particular the preparation of the slurries and the firing stages. Energy production processes generally have a great influence on most of the impact categories considered.

This LCA study is part of a business innovation project promoted by an Italian ceramic company. Its aim is to quantify the Carbon Footprint and the impact on other relevant environmental topics caused by specific stages in the production process of porcelain stoneware tiles, before and after project implementation (*ante-operam* and *post-operam* scenarios). In order to promote a more complete environmental impacts evaluation, the study includes also a Risk Assessment (RA) analysis, investigating the local effects of ceramic powders emission into the atmosphere through the Gaussian plume model "WinDimula 3.0", developed by ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) and the company Maind S.r.l.. The use of the two different types of impact assessment tools allows for a scenarios' comparison both from a site-generic point of view (LCA) and a site-specific one (RA).

2. Materials and methods

2.1 Case study and scenarios description

The aim of the company's project focuses on the development of a new edge-grinding powders management system. Edge-grinding is the tile squaring and finishing mechanical process, implemented through dedicated machinery, after firing and cutting in selected formats. The edge-grinding process creates a pulverulent material, characterized by grain size generally between 1 μm and 400 μm. These powders can be treated either as waste or as by-product (Confindustria Ceramica, 2017). Three scenarios have been analysed.

The *ante-operam* scenario concerns the recovery of the edge-grinding powders through a "wet" method, their mixing with mechanical shovels in dedicated boxes and their transport via conveyor belt to wet mills for the raw materials grinding, upstream of the porcelain stoneware tiles' production.

In the *post-operam* scenario, the above described “wet” method is used just for a small percentage of the edge-grinding powders (5%). The great majority of powders (95%) is loaded as it is through pneumatic transport in fixed silos, and then directly transported via a conveyor belt inside wet mills. In this way, the powders mixing with mechanical shovels and their subsequent dispersion in the atmosphere, causing the material loss and potential problems related to the possible inhalation by workers, is substantially reduced.

At last, the *disposal* scenario is also considered in order to compare the impacts related to the two recycling scenarios with those related to a disposal one. The disposal in inert waste landfill was the powders management once operated by the company, and it is still permitted by Italian legislation. In this scenario, the powders are loaded via pneumatic transport inside mobile silos and then transported to the inert waste landfill by dedicated trucks.

2.2 Application of the LCA methodology

LCA is a standardized, operational, multi-criteria international tool for assessing environmental impacts within the entire life cycle of a product or service, in order to promote environmental improvement and avoid burden shifting. An LCA comparison of the three above mentioned management options of ceramic edge-grinding powders is described below. The attributional LCA approach is adopted.

LCA system boundaries include the treatment processes of the powders from their suction after the edge-grinding stage to their loading into the wet mills (if recycled as a secondary raw material in “ante-operam” and “post-operam” scenarios) or to their inert waste landfill disposal (if managed as waste in disposal scenario).

This study considers only the environmental impacts related to the management operations and not those related to the whole life cycle of the powders. For this reason, both impacts of powders generation and those caused by the production of the tiles are not included within the system boundaries. However, in order to make a comparison on the same functional unit, in the disposal scenario system boundaries expansion is applied to include the extraction of raw materials necessary to replace the non-recycled powders. This is also applied in the recycling scenarios to replace the percentage of powders dispersed into the atmosphere.

The system function is the management of the powders generated during edge-grinding. The selected functional unit is 1 tonne of edge-grinding powders.

2.2.1 Inventory data, calculation software and database

This study is based both on primary data provided directly by the ceramic company from field measurements, internal databases and technical specification, and on secondary data from Ecoinvent 3.4 database (Ecoinvent Centre, 2017; <www.ecoinvent.org/database/database.html>). Primary data refer to the years 2018 and 2019. The software used is openLCA v. 1.7 (GreenDelta, 2017; <www.openlca.org>).

2.2.1 Life Cycle Impact Assessment

Life Cycle Impact Assessment is carried out using the characterization methods recommended by ILCD Handbook (EC-JRC, 2011), considering the following impact categories: 100-years climate change (GWP) excluded biogenic CO_2, ozone depletion (OD), acidification (AC), photochemical ozone formation (POF), freshwater eutrophication (EuF), marine eutrophication (EuM), particulate matter (PM), and water depletion (WD). Cumulative energy demand (CED) is calculated too.

2.3 Application of WinDimula 3.0 model

WinDimula 3.0 is a gaussian plume model (Hanna et al., 1982) that allows to calculate the concentrations and soil depositions of airborne non-reactive pollutants emitted from different types of sources in correspondence of computing domain receptors. The use of this kind of simulation models is significant for the identification of environmental protection effective strategies, as an important complement to traditional air quality monitoring techniques. In fact, these Risk Assessment tools help to recognize the correlations between the causes of pollution (emissions) and the effects (concentration of pollutants in the atmosphere) (Righi et al., 2009).

The WinDimula model is applied in Short Term mode for a full representative year, in order to compare the concentration in the atmosphere of the edge-grinding powders generated in ante-operam and post-operam scenarios. According to the Ceramic Centre of Bologna (personal communication), the most critical substance in fired ceramic powders is respirable crystalline silica, declared carcinogenic by the EU Directive 2398/2017 (European Union, 2017). Therefore, in this study, respirable crystalline silica is considered as index substance for the health risk assessment related to the analyzed processes. Since the dispersion and the subsequent deposition of the powders occur mostly within the plant area, the obtained concentration of the powders respirable fraction is compared with the Occupational Exposure Limit Value (OELV). For the comparison, respirable crystalline silica Threshold Limit Value - Time Weighted Average (TLV-TWA) of American Conference of Governmental Industrial Hygienists (ACGIH) is taken into account (0.025 mg/m3). In the model, powder emission (D50= 21.4 µm), is treated, conservatively, as a PM10 emission, with a sedimentation rate of 0.15 m/s. As regards meteorological data, 8763 average hourly meteorological records referring to a time span of one year (2016) are considered as representative of the weather conditions in the production plants area.

Finally, to obtain a significant graphical visualization of the results to be compared with the OELV, a 100 m*100 m calculation's grid is used.

3. Results

3.1 LCA results

LCA results (see Table 1, Figure 1 and Figure 2) show that for all considered impact categories excluding PM, the inert waste landfill disposal scenario has the highest environmental burden, with impact score values of at least one order of magnitude higher than the two recycling scenarios. In particular, the reduction of environmental impacts from disposal to recycling scenarios is largely due to the use of edge-grinding powders as secondary raw material, avoiding primary raw materials extraction, processing and transport operations. Usually, the highest contribution comes from fossil fuel energy consumption during raw materials production, consistently with results reported in scientific literature.

Table 1 - LCIA results for disposal, ante-operam and post-operam scenarios

Impact category	*Unit*	*Disposal scenario*	*Ante-operam scenario*	*Post-operam scenario*
AC	mole H^+ eq.	5.5E-01	4.8E-02	2.4E-02
GWP	kg CO_2 eq.	9.2E+01	1.2E+01	7.8E+00
EuF	kg P eq.	3.1E-02	2.2E-03	7.7E-04
EuM	kg N eq.	1.2E-01	1.0E-02	5.7E-03
OD	kg CFC-11 eq.	1.4E-05	1.6E-06	9.2E-07
PM	kg PM2,5 eq.	6.8E-02	2.9E+00	1.4E-01
POF	kg NMVOC eq.	3.6E-01	3.0E-02	1.7E-02
WD	m^3 eq.	2.2E+01	1.2E+00	1.6E-01
CED	MJ	1.6E+03	2.1E+02	1.4E+02

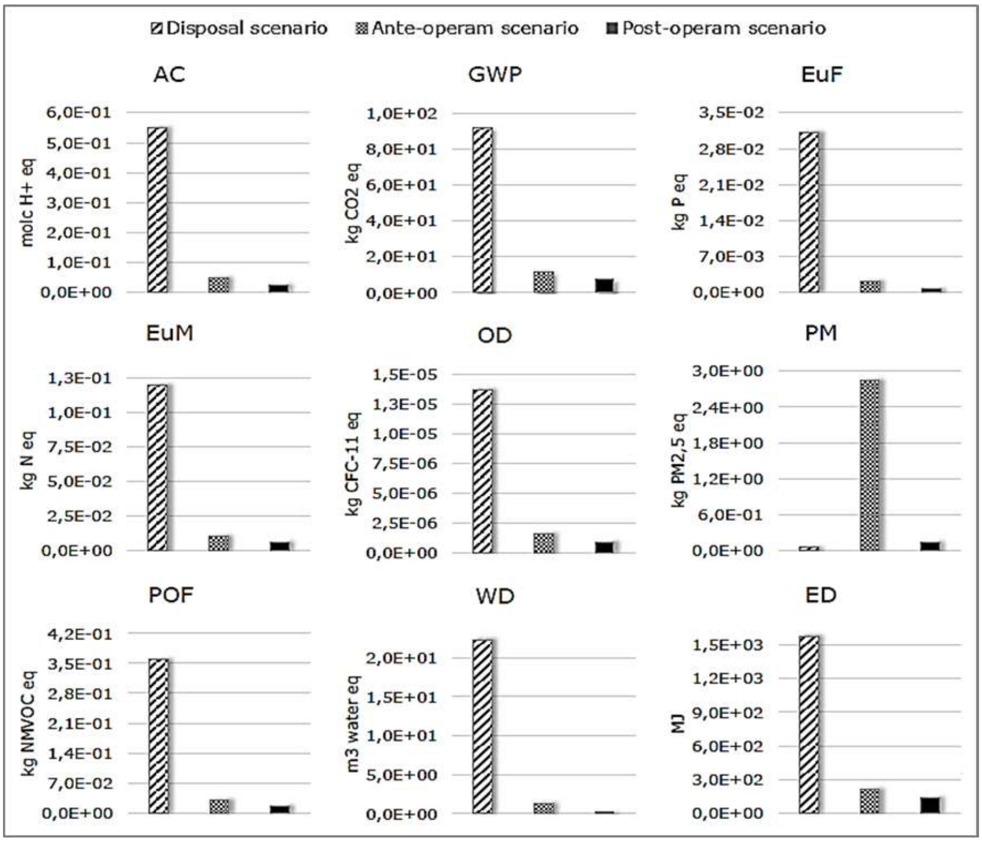

Figure 1 - Graphical representation of the LCIA results for the analysed scenarios and impact categories

The results of PM impact category substantially differ from this trend. In this category, ante-operam scenario shows the highest impacts, also compared to the disposal scenario. Impacts are mainly due to the handling operated by mechanical shovels, with subsequent dispersion into the atmosphere of an estimated 5% of the pulverulent material managed at this stage. In post-operam scenario, the implemented plant improvements allow for the management of most of the powders inside closed systems, so to avoid dispersion. In disposal scenario, no powders are emitted into the atmosphere within the company's boundaries, since the material is loaded by pneumatic transport directly into mobile silos; however, in this scenario there are emissions related to the transport and landfill management processes, taken into consideration in the relative datasets.

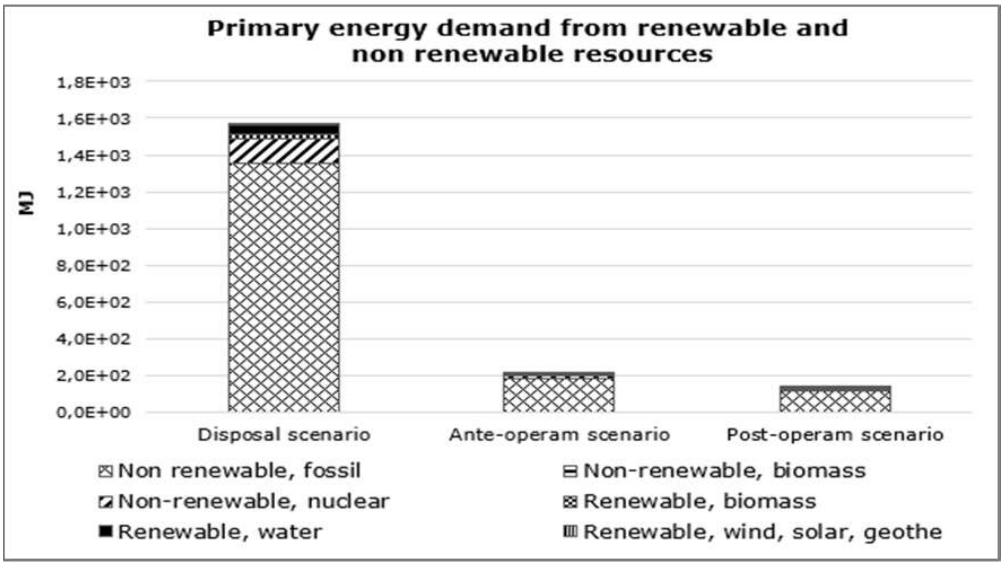

Figure 2 – Primary energy demand from renewable and non-renewable resources impact category; results for disposal, ante-operam and post-operam scenarios

Considering the obtained results, a sensitivity analysis is carried out on the edge-grinding powders' emission into the atmosphere, in relation to PM impact category. A linear correlation between the amount of dispersed powders and the indicator value is found: for example, by reducing of 20% the considered amount of dispersed powders (i.e. reducing from 5% to 4% of the total managed amount), the impact decreases by 20.7%. The data is therefore sensitive, meaning that a small change of the value assigned to the dispersed powder results in a wide variation of the impact result. For a better estimate of the impacts related to PM emissions, a more precise evaluation of the ratio of dispersed powders is recommended.

To compare and understand local effects of the powder emission in ante-operam and post-operam scenarios, WinDimula 3.0 model is also applied in this study.

3.2 WinDimula model results

Results are shown in Figure 3. In the ante-operam scenario, respirable crystalline silica TLV-TWA is exceeded in an area up to 50 metres from the emission source. In the remaining part of the grid, the threshold value is not exceeded. In the post-operam scenario, exceedances occur in limited and restricted areas within the first 10 metres from the source. Based on these results, plant improvements in the post-operam scenario allow for a 95% reduction in the powders atmospheric concentration.

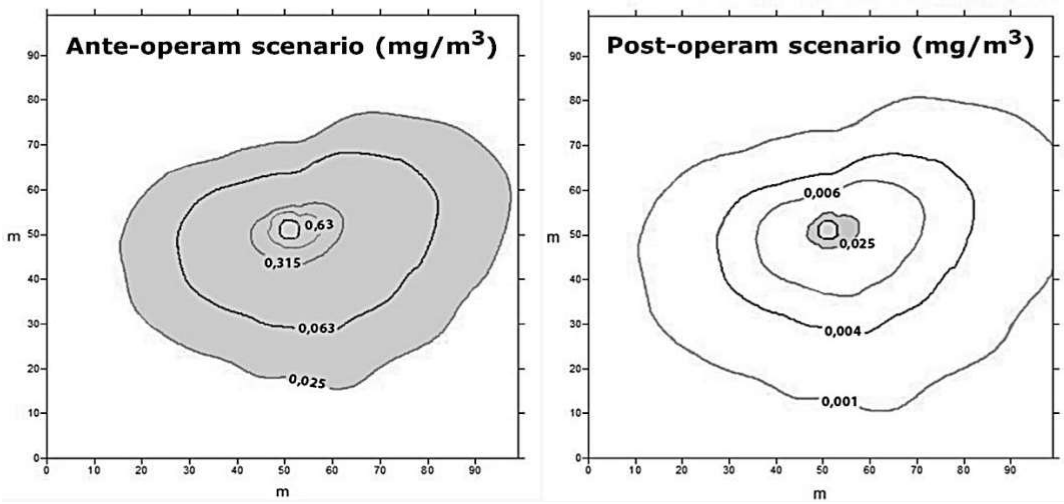

Figure 3 – Respirable fraction concentration isolines: ante-operam and post-operam scenarios (in the centre, the schematic representation of the areal source considered by the model)

It is important to note that the study is carried out with a conservative approach, considering both all the powders emission as PM10 and the respirable fraction entirely composed of crystalline silica. In addition, the amount of dispersed powder is estimated and not measured; the sensitivity analysis carried out (although on a different indicator based on a different model), shows that the impact may vary considerably with the input fluctuation. Finally, the fact that the source area has a size comparable to that of the grid's unit, the concentrations estimated by WinDimula near the source, which are the most affected by software's approximations, may present significant approximation errors. For all these reasons, the calculated dispersion curve of hazardous or carcinogenic substances concentration, such as crystalline silica with very low TLV-TWA limit, should be confirmed by ad hoc sampling and analysis, which are beyond the scope of this study.

Anyway, the difference in exposure risk between the two scenarios is significant, showing that the risk to workers' health is reduced by the proposed innovation project improvements.

4. Conclusions and recommendations

This analysis, in addition to increase producer awareness of the sustainability concept, confirms the effectiveness of the circular economy approach promoted by the European Union for the ceramic tiles sector, showing that the recycling of edge-grinding powders as a secondary raw material results in a reduction of the environmental impacts. The internal recycling and the prevention of powder loss and dispersion into the atmosphere also allow environmental burdens not to be shifted from one impact category to another. The use of a site-specific tool like WinDimula 3.0 allows for increasing the knowledge of the specific process impacts and identifying critical points not identifiable with a large-scale point of view, demonstrating the importance of a complementary use of assessment methods. A more complete and holistic vision of the systems complexity can orient in more conscious and correct ways the choices to be made for environmentally sound improvements and a truly sustainable development.

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