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Review

An analysis of the use of life cycle assessment for waste co-incineration in cement kilns

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A B S T R A C T

Life cycle assessment, LCA, has become a key methodology to evaluate the environmental performance of products, services and processes and it is considered a powerful tool for decision makers. Waste treatment options are frequently evaluated using LCA methodologies in order to determine the option with the lowest environmental impact. Due to the approximate nature of LCA, where results are highly influenced by the assumptions made in the definition of the system, this methodology has certain non-negligible limitations. Because of that, the use of LCA to assess waste co-incineration in cement kilns is reviewed in this paper, with a special attention to those key inventory results highly dependent on the initial assumptions made. Therefore, the main focus of this paper is the life cycle inventory, LCI, of carbon emissions, primary energy and air emissions. When the focus is made on cement production, a tonne of cement is usually the functional unit. In this case, waste co-incineration has a non-significant role on CO_2 emissions from the cement kiln and an important energy efficiency loss can be deduced from the industry performance data, which is rarely taken into account by LCA practitioners. If cement kilns are considered as another waste treatment option, the functional unit is usually 1 t of waste to be treated. In this case, it has been observed that contradictory results may arise depending on the initial assumptions, generating high uncertainty in the results. Air emissions, as heavy metals, are quite relevant when assessing waste co-incineration, as the amount of pollutants in the input are increased. Constant transfer factors are mainly used for heavy metals, but it may not be the correct approach for mercury emissions.

Contents

Abbreviations: BREF, best available techniques reference document; CEM I, Portland cement as a defined type of cement; CO, carbon monoxide; CO_2, carbon dioxide; EIA, environmental impact assessment; GHG, green house gas; HCl, hydrogen chloride; HF, hydrogen fluoride; Hg, mercury; H_2O, water; kg, kilogramme; kJ, kilojoule; LCA, life cycle analysis; MBT, mechanical biological treatment; MJ, megajoule; m_{input}, material input; m_{output}, material output; N_2, nitrogen (as gas); MSWIP, municipal solid waste incineration plant; NH_3, ammonia; NO_x, nitrogen oxides; O_2, oxygen (as gas); PCDD/F, polychlorinated dibenzo-*p*-dioxins and furans; SO_2, sulphur dioxide; TF, transfer factor; SRF, solid recovered fuel; US, United States of America; VDZ, Verein deutscher Zemenwerke; VOC, volatile organic compounds.

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1. Introduction

Today, there are many tools and indicators available for evaluating, assessing and benchmarking of the environmental performance of processes, process chains or systems (e.g. Finnveden and Moberg, 2005; Ness et al., 2007). Important examples include

- Life cycle assessment (LCA).
- Environmental impact assessment (EIA).
- Strategic environmental assessment (SEA).
- Environmental risk assessment (ERA), also called ecological risk assessment.
- Material flow analysis (MFA).
- Ecological footprinting.
- Cost-benefit analysis (CBA).
- System of economic and environmental accounting (SEEA).

Specifically with regard to industrial or commercial installations, LCA and EIA can be used in a complementary way. Thereby, EIA is often seen as a location-specific environmental evaluation approach for which LCA is less suitable (Tukker, 2000). However, it has to be noted that LCA is an analytical tool specifically designed to assess the environmental impacts relating to the whole production chain of a good, whereas EIA is a procedure that has to support decision making with regard to environmental aspects of a much broader range of activities (Tukker, 2000). In the field of waste management, LCA has become a common methodology on the assessment of treatment options in order to help decision-making, as it allows the identification of treatment options with less environmental impact. In particular, the environmental performance of waste co-incineration has frequently been assessed through LCA methodology. LCA results are dependent on the quality of the raw data and on their capacity to represent the real full life cycle. Results are always subject to a certain degree of uncertainty, and main conclusions from LCA should always be derived taking into account the inherent limitations of the method.

By definition, LCA is a tool to assess the potential environmental impacts and resources used throughout a product's lifecycle, i.e., from raw material acquisition, via production and use phases, to waste management (ISO 14040-LCA, 2006a). The term 'product' includes both goods and services (ISO 14040-LCA, 2006b). LCA is a comprehensive assessment and considers all attributes or aspects of natural environment, human health, and resources (ISO 14040-LCA, 2006a) and it is useful in order to avoid problem-shifting, for example, from one phase of the life-cycle to another, from one region to another, or from one environmental problem to another (Finnveden et al., 2009). In this respect, all the steps of manufacturing a product should be included, from the extraction of raw materials, supply chain, manufacturing, distribution, use, and waste treatment (reuse, recycling or final disposal) in a cradle to grave approach. Four main steps are carried out in any LCA study: Goal and Scope definition, Inventory analysis (LCI), Impact assessment (LCIA) and Interpretation of results.

On the understanding of LCA, the scientific method applied plays an important role, as LCA can be interpreted as a part of a theoretical prediction with actual, observed phenomena (Guinée, 2004). Although standards exist, many methodological choices are still available for individual studies, and it needs to be understood that LCA environmental information is not complete, and not necessarily absolutely objective nor accurate (Ekvall et al., 2007). Final results tend to be highly influenced by methodological decisions, the choice of the functional unit, system boundaries, time perspective, the parameters considered, assumptions made, sources of data, allocation approach used and the chosen impact assessment method (Ekvall et al., 2007; Van den Heede and De Belie, 2012).

This paper is intended as a critical analysis of existing LCA studies on waste co-incineration in cement kilns. Co-processing of waste in cement plants comprises the use of waste-derived fuels and raw materials. The co-processing of waste-derived fuels is also called co-incineration, which became very important within many countries around the world, especially in Europe. The published results of life cycle inventories and environmental impact assessment of waste co-processing, specifically the co-incineration of waste-derived fuels, have been assessed in this paper, with the main objective of evaluating their assumptions, implications, limitations and main conclusions obtained from the application of different methodology frameworks.

2. Cement production and co-incineration of waste-derived fuels

Cement is a hydraulic binder used for the manufacturing of mortar and concrete. Concrete (i.e. cement) is one of the World's most significant manufactured materials (Huntzinger and Eatmon,

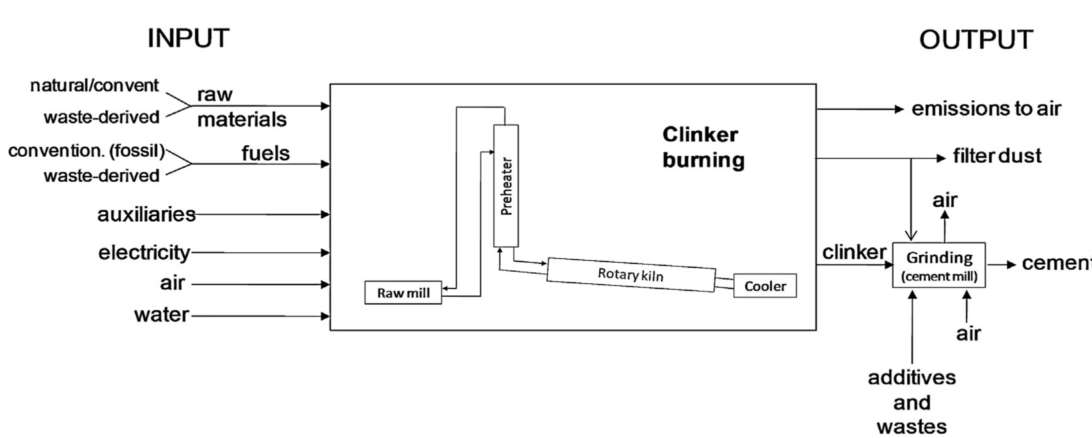

Fig. 1. Scheme on the principle input and output of cement plants.