

The Materials and Energy Potential Method for the Quantitative Distinction Between Waste Valorization and Elimination in the Cement Industry

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Abstract

A quantitative method is proposed to distinguish between the valorization and elimination of waste in a cement kiln. Examples are presented to illustrate the consequences of the developed approach. These examples are related to the process conditions in the kiln in the dry- and the wet-cement process.

The Materials and Energy Potential (MEP) method which is presented in this report is based on the recognition that a specific waste can contribute to the cement-making process as an alternative raw material and, at the same time, as a source of energy. The paper is based on a report prepared for Febelcem, the Federation of the Belgian Cement Industry.

Introduction

A quantitative method is proposed to distinguish between the valorization and elimination of waste in a cement kiln. Examples are presented to illustrate the consequences of the developed approach. These examples are related to the process conditions in the kiln in the dry- and the wet-cement process.

Valorization is defined as the processing of a waste in a cement kiln to substitute raw materials and/or fuels. In this case, the waste contributes, in a positive way, to the cement production process.

Waste combustion in a cement kiln without any substitution or process improvement and with the sole purpose of final waste processing is defined as elimination.

The differentiation between elimination and valorization is of importance as regulations distinguish between waste elimination and valorization. For instance, directives of the European Union allow the export of waste for the purpose of valorization.

Proposals to distinguish between valorization and elimination

A review of earlier proposed methods to define valorization shows that most approaches are based on the comparison of the waste with a fuel and that a clear appreciation of both the energy and the raw material value of a waste does not yet exist.

Examples of conditions on calorific value or raw materials content are:

- In Germany, according to the "Kreislaufgesetz", the energy content has to be larger than 11 MJ/kg and the fuel efficiency must be at least 75 %. Conditions on raw materials content have not been published.
- The Ministry of the Environment (VROM) in the Netherlands sets a calorific value limit of 15 MJ/kg and states that only liquids can be processed (valorized) properly in a cement kiln (i.e. no sludges

and no solids). In a former paper, a limit had been proposed of 18 MJ/kg or a useful ash content exceeding 50%.

- In France, based on EC Directive 94/67, energy recovery for the cement industry is recognized from 5 MJ/kg.
- In a proposition to BUWAL and in an OVAM paper, it is proposition that processing of a waste can only be regarded as valorization if the calorific value exceeds 25 MJ/kg and the contaminants in the waste do not exceed the given concentration limits or the calorific value exceeds 15 MJ/kg and the concentration of the contaminants in the waste does not exceed the limits, and the total concentration of Ca, Si, Al and Fe is larger than 10 %.

General conditions for waste processing

In order to have an acceptable treatment of waste in a cement kiln, some general conditions have to be met:

- permit conditions and emission standards must be met;
- the quality of the cement must fulfil limits with respect to its structural capabilities and its environmental compatibility;
- the production process must not be impaired and the safety of the workplace must be ensured;
- an environmental assessment should show that the cement process must be the best way of handling the waste materials. In this assessment, the cement option should be compared with alternatives such as reuse, recycling, incineration in specialized waste combustion facilities or other facilities;
- the waste materials should not be mixed in order to reach the maximum allowable limits of contaminants in the waste.

These requirements result in criteria which limit the quantity of secondary materials used or can exclude specific wastes entirely. Several criteria have been formulated in the literature and are related to gaseous emissions, cement quality, health standards, and reactor maintenance.

These criteria are necessary conditions for the application of waste in general, but do not determine the difference between elimination of waste or valorization. When these conditions are not met, the waste considered cannot be treated in a cement kiln: processing is not acceptable.

Valorization or elimination

The method which is presented in this paper is based on the recognition that a specific waste can contribute to the cement-making process as an alternative raw material and, at the same time, as a source of energy. This is a specific advantage of waste processing in the cement process which is expressed in the assessment method: the Materials and Energy Potential (MEP) method.

Essential steps in the development of the proposed method are:

- division of the waste in a raw materials fraction and the rest or energy fraction which is separately evaluated as a source of energy;

- quantitative measures for the raw materials content and the value of the energy fraction are developed;
- based on these measures, an assessment of waste processing as valorization or elimination is proposed.

Below, the decision scheme is shown to decide upon valorization or elimination of a waste in a cement kiln following the MEP method.

Another essential aspect of the proposed method is the interpretation of the term “source of energy”. In this study, a “source of energy” is distinguished from a “fuel” with calorific values of 15 MJ/kg up to 40 MJ/kg (wood, coal, oil). The starting point chosen is that any energy contribution (to the cement process) is sufficient for the classification “energy source”.

Definition of raw materials fraction

First, the raw materials part is established. This fraction contains the components that are useful to (functional in) the cement process: CaO (CaCO₃), SiO₂, Al₂O₃, Fe₂O₃ and SO₃. The other inorganic components (including water) in the waste are allocated to the raw materials fraction up to maximum values, mwaf and maif, by which the fraction functional components is allowed to contain an equivalent amount of water and non-functional components as occur in natural raw materials. If Ca occurs as CaCO₃, the CaCO₃ quantity is allocated to the raw materials fraction. The following expression is used to calculate the measure **M** for the raw materials value of the waste:

$$M = usmf / (1 - minw) (1 - mini)$$

wherein:

usmf = fraction of useful materials in waste as such
 waf = water fraction in waste as such
 inf = fraction of inert, non-functional components in the waste
 mwaf = maximum water fraction allowed in raw materials fraction
 maif = maximum inert fraction allowed in raw materials fraction
 mini = minimum value of inf and maif
 minw = minimum value of waf and mwaf.

Example 1: For the dry-cement process, the raw materials fraction can contain up to 15 % water. In this report, a maximum of 10% is used as an example for the non-functional part of the raw materials. So, for the dry-cement process mwaf = 0.15 and maif = 0.10.

Example 2: For the wet-cement process, up to 30 % water and the same percentage, 10, of non-functional (inert and trace) elements are allocated to the raw materials fraction, comparable to the natural raw materials. Again, as an example a maximum of 10% non-functional components is used for the non-functional part of the raw materials fraction. So, for the wet-cement process mwaf = 0.30 and maif = 0.10.

Assessment of waste as a source of energy

Secondly, the energy value of the rest or energy fraction (= waste minus raw materials fraction) is expressed in a measure E . It is proposed to consider the combustion of a material as energy valorization if the autothermal combustion temperature, calculated for the actual conditions in the cement kiln, exceeds a required minimum process temperature,

For the measure for the energetic value of a material in a process, E , the following expression is introduced:

$$E = (T_{\text{comb}} - T_o) / (T_{\text{ref}} - T_o)$$

wherein:

T_{ref} = an essential reference temperature level in the process to be reached ($^{\circ}\text{C}$)

T_{comb} = the autothermal combustion temperature of the considered material under the prevailing process conditions ($^{\circ}\text{C}$)

T_o = an initial temperature level in the process to be considered as the starting temperature for the heating process ($^{\circ}\text{C}$).

E expresses relatively the extent to which the required temperature level, T_{ref} , is reached or exceeded by the combustion of the energy fraction. This being the case, the material is able to contribute to the energy needs of the process. T_o expresses a basic temperature to be used as the initial temperature for calculating T_{comb} . For example, T_o could be the combustion air temperature at the inlet of the kiln.

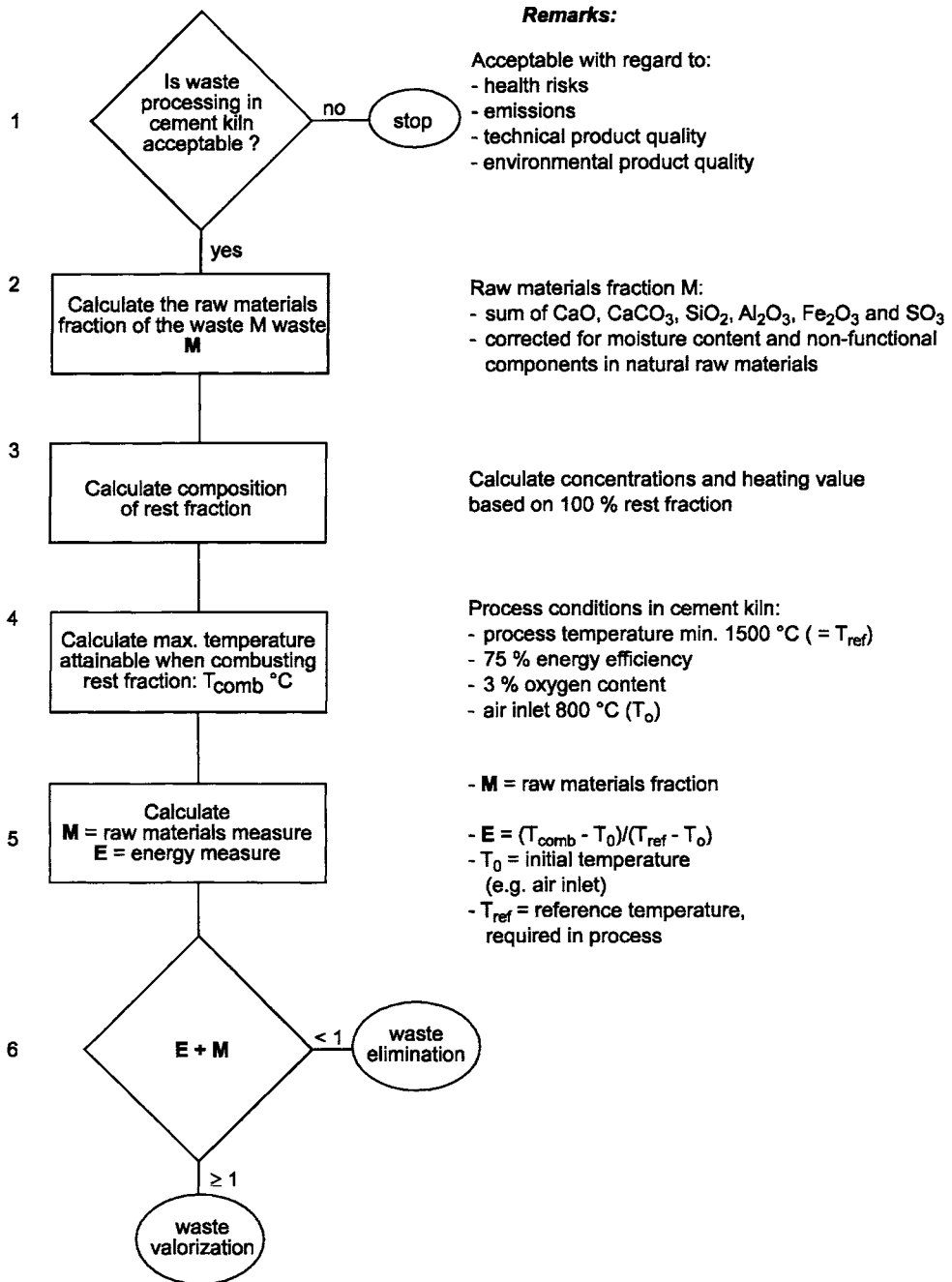
As a consequence of the above, a material with the composition of the energy fraction is valorized as a source of energy if:

$$E \geq 1$$

Example: For the dry- as well as for the wet-cement process T_{ref} is set at 1500°C , exceeding the minimum required temperature for clinker formation of 1450°C . The process conditions to calculate the combustion temperature are: an oxygen concentration of 3 %, an inlet temperature of the air of 800°C ($= T_o$) and an energy efficiency of 75 %. Thus, the E measure is calculated as:

$$E = (T_{\text{comb}} - 800) / (1500 - 800)$$

Decision scheme for waste valorization in a cement kiln.



Generalized assessment of a waste as a source of raw materials and energy

For the general assesment of processing a waste with a raw materials and an energy part, the Materials and Energy Potential of the waste, defined as the sum of **M** and **E**, is proposed as a measure. It follows from the starting points referred to above that processing a waste with $E \geq 1$ or $M=1$ in the cement kiln is a case of valorization.

It is proposed generally to consider processing of a waste in a cement kiln as valorization when

$$E + M \geq 1$$

This relation is the basis for the Materials and Energy Potential method presented in this study. **E** is calculated from the energy fraction, **M** from the raw materials fraction. Examples are presented to show the consequences of this method that enables a quantitative distinction between valorization and elimination. For wastes with an **M** value of nearly 1, the formulated condition may be too strict.

The result of the appreciation of the raw materials aspect is that TNO's MEP method favours processing of wastes with a raw materials component in the cement kiln. The allocation of (part of the) water in the waste to the raw material fraction is favours the processing of wet wastes in the wet-cement process. Generally, however, from the results of the calculations for actually applied as well as for artificially composed wastes, it is concluded, that in many cases the conclusion is the same for the wet process as for the dry process.

In the following table, some calculations are presented as example.

↓ → waste characteristics		Organic solvent	Filtration earth	Artificial waste	Filter cake	LD slag
LHV *	(MJ/kg)	25	12.5	3.4	6	0
water	(%)	20	20	50	50	5
ash	(%)	-	50	20	20	95
Dry-cement process						
T _{comb} (excl. raw materials fraction) (°C)		1873	1912	1151	1400	-
M	(-)	0	0.59	0.24	0.24	1.0
E	(-)	1.53	1.75	0.50	0.86	-
E + M	(-)	1.53	2.45	0.74	1.09	1.0
Valorization		YES	YES	NO	YES	YES
Wet-cement process						
T _{comb} (excl. raw materials fraction) (°C)		1873	2023	1212	1476	-
M	(-)	0	0.70	0.29	0.29	1.0
E	(-)	1.53	1.75	0.59	0.96	0
E + M	(-)	1.53	2.45	0.88	1.25	1.00
Valorization		YES	YES	NO	YES	YES

* Lower Heating Value of waste as such

Conclusions

- The main types of criteria for waste treatment in a cement process discussed in literature are conditions for emission standards, limits on concentrations of contaminants in the waste and limits with respect to cement quality. These aspects do not distinguish between valorization and elimination; cement processes in which wastes are used have to respect these limits whether valorization or elimination is at stake.
- Generally, it can be concluded that in Germany, Belgium and The Netherlands, the issue of valorization and elimination has not been worked out on process technological considerations only, which explains the widely different ranges of criteria. Proposed conditions are mainly based on limits to heating values. Raw material aspects are hardly discussed.
- The MEP method is based on the recognition that a specific waste can contribute to the cement-making process at the same time as an alternative raw material and as a source of energy. This is a specific advantage of waste processing in the cement process.
- The MEP method favours processing of wastes with a raw materials component in the cement kiln.
- Non-functional compounds (Mg, P, Na-, K components and trace elements) are allowed in the raw materials fraction up to a preliminary maximum of 10 %. A better justified value should result from a study of quantities occurring in natural raw materials.