COMPARISON BETWEEN ECO-PROFILES OF INNOVATIVE NANOCLAY AND TRADITIONAL TBBPA FLAME RETARDANTS

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Introduction

Life Cycle Assessment – LCA is a tool to calculate the environmental burden associated to a process/product that is internationally regulated by ISO 14040 series and widely applied at European/world level. The methodology is commonly used to supply management strategies with particular attention to the choice between alternative processes or products [1].
In this work, a "*cradle to gate*" [2] approach has been applied to TBBPA (tetrabromobisphenol-A) and nanoclays production processes in order to compare a traditional halogenated flame retardant (FR) with an innovative class of nanofiller which is very promising for their FR properties.

Objectives

Polymeric materials have to express in many cases fire retardancy properties, which are conferred by additives, usually constituted by halogen based systems. In the last decades, fire experience shows that when halogenated flame retardants are exposed to a flame and perform their fire retardant action, they induce the formation of substances that are now recognised as a major health and pollution hazard for people and environment. The emission of such substances can also occur during the production process and end-of-life treatments, in particular in the case of recycling operations, not fulfilling the sustainable development guidelines. For these reasons, great efforts have been devoted to the study of new classes of environmentally friendly FR and in particular on the effect of the addition of nanofillers (such as carbon nanotubes, polyhedral silesquioxanes and nanoclays) to the polymeric matrices.
In contrast to microfillers, a few weight percent of nanofillers (typically less than 5%) are sufficient to convert polymer properties from bulk into interfacial developing enhanced engineering properties, e.g. improved toughness/stiffness/dimensional stability, thermal stability, barrier resistance, surface adhesion, reduced warpage, low stress, and fire retardancy. The current state-of-the-art for silicate polymer nanocomposites is mainly based on layered clay-type silicates [3] [4].
Altough the intercalation chemistry of polymers when mxed with appropriately modified layered silicates and synthetic layered silicates has long been known, the field of polymer layered silicates nanocomposites has gained momentum only recently. Two major findings have stimulated the revival of interest in these materials: first, the report of Toyota research group of a Nylon-6/montmorillonite nanocomposite for which very small amount of layered silicate loadings resulted in pronounced of improvements of thermal and mechanical properties [5] and second, the observation by Vaia et al. [6] that it is possible to melt mix polymers with layered silicates without the use of solvents.
Life Cycle Analysis of such innovative nanostructured FR is of major interest; the final goal being the comparison between the energetic and environmental burdens of new FR in relation to the conventional halogenated ones.
In this context, a first comparison has been established between the production of TBBPA and nanoclays developed in the framework of the NANOFIRE project.

System boundaries and functional unit

According to ISO 14040, the system boundaries determine which unit processes have been included within the LCA study [7]. Figures 1 and 2 show the system boundaries for TBBPA and nanoclays production respectively. In particular, data about TBBPA technology come from literature (*secondary data*) while data concerning nanoclays production have been directly supplied by a NANOFIRE partner (*primary data*).

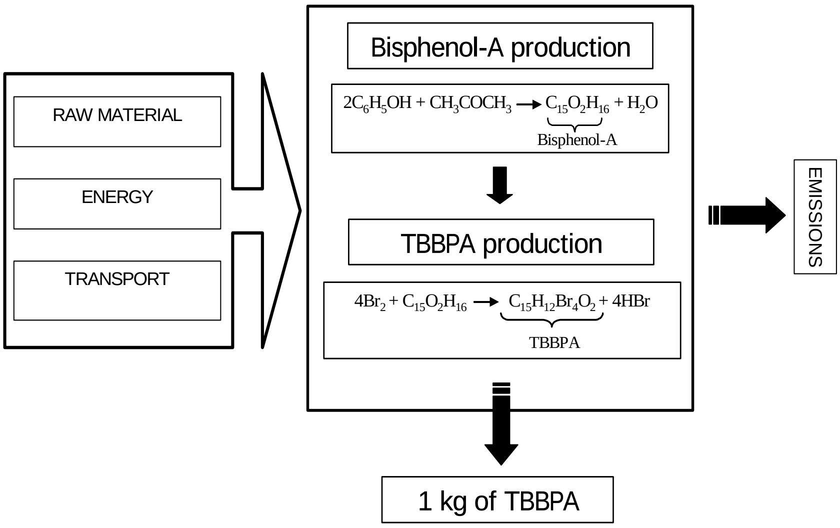

Fig. 1 – System boundaries of TBBPA production

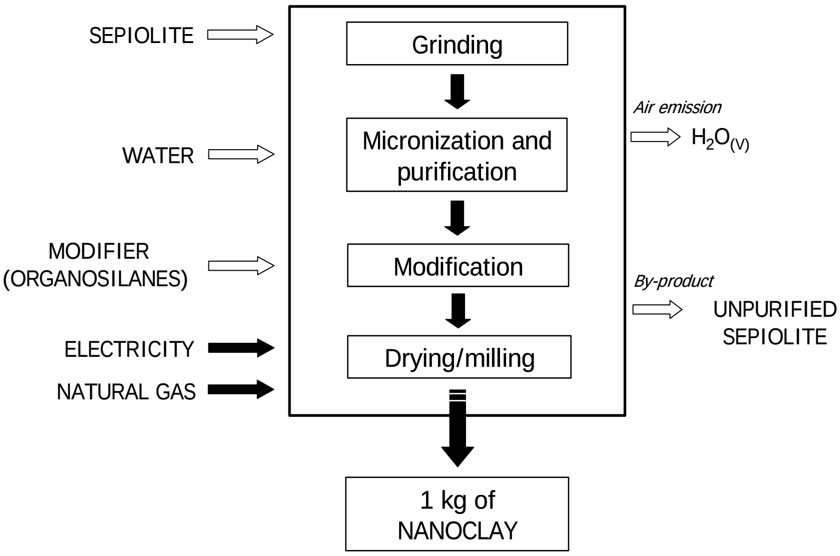

Fig. 2 – System boundaries of nanoclays production (Source: NANOFIRE partner)

The functional unit is a measure of the performance of the functional outputs of the product systems and its primary purpose is to provide a reference to which inputs, outputs and results are related [2]. As shown in the figures, the functional unit of the systems analysed is 1 kg of product.
The Boustead v.5 software was used as calculation model and as main source of secondary data. In both cases, the obtained results refer to the Spanish energy mix.

Results

The results of the LCA are splitted into the following categories: **energy results**, represented by GER - *Gross Energy Requirements* indicator (expressed as MJ/kg), that characterize the energy consumption for each functional unit, and **environmental results**, concerning natural resources consumption, air emissions, water emissions and solid wastes for each functional unit.
In this paper, the above-mentioned environmental results will be not explicitly reported; however, according to ISO 14042, they will be converted into environmental indicators by means of several standardised mandatory elements. For this analysis, the following impact categories are considered: Greenhouse effect (GWP_{100} - Global Warming Potential) expressed as kg-CO_2-eq./kg and Acidification (AP - Acidification Potential) expressed as mol H^+-eq./kg.

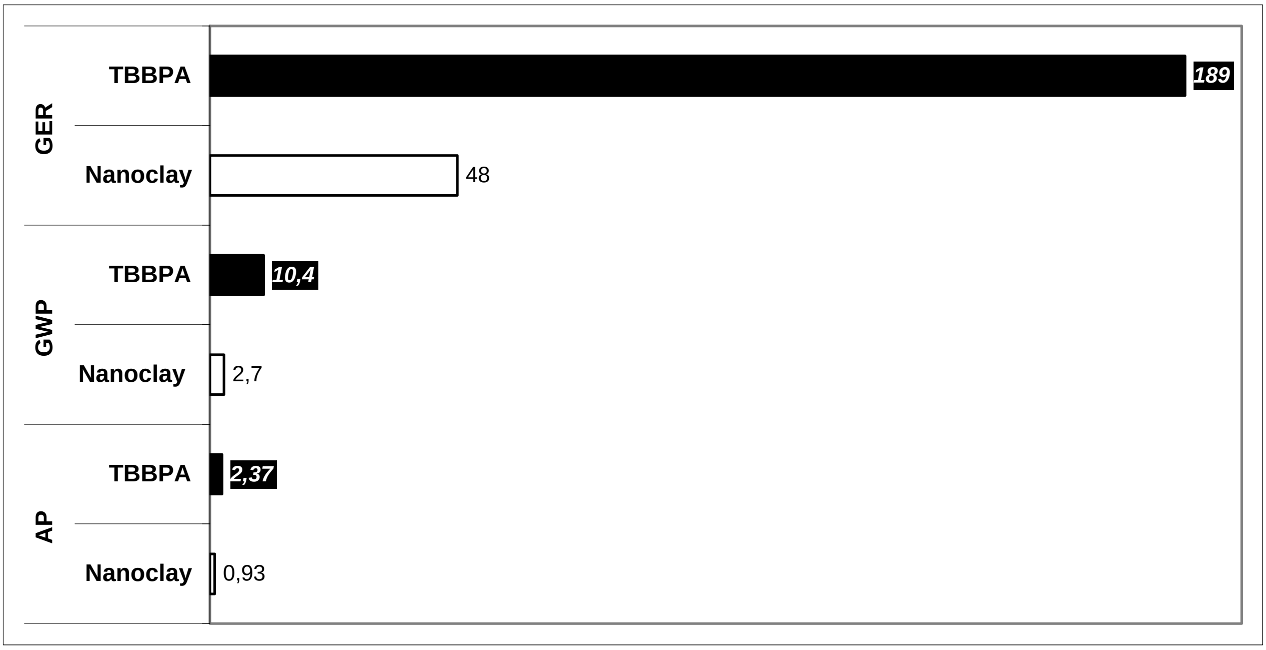

Fig. 3 – Main LCA results associated to the two systems compared

From an energy consumption viewpoint, nanoclays production require a lower quantity of process energy with respect to the TBBPA. This is the reason why the main global impact indicators associated to TBBPA production are higher than nanoclay system.
Due to the lower content of additive materials in the polymeric mix and to the absence of degradation with the temperature, nanoclays are also expected to be more recyclable and less hazardous in the case of fire accident in comparison with halogen containing FR polymer materials. Such characteristics added to the low technological impact of the production process, makes this nanofiller extremely appealing for the industrial applications.

Conclusions

From the evaluation of the main global environmental impact indicators, it can be observed that the TBBPA production process involves high Gross Energy values and significant environmental impact, in particular Global Warming Potentials and Acidification Potential. Crucial importance assumes also the local impact in case of fire accident and end-of-life treatments that are negligible in the case of nanoclays but considerable for TBBPA due to the emissions of hazardous substances. Therefore, nanoclays are very promising as nanofiller with FR property and the LCA results justifies the great interest to the study of innovative classes of environmentally friendly nanostructured FR materials for polymer matrices.

If the NANOFIRE project will confirm the properties of nanoclays as FR, it is possible to state that this technological improvement constitutes a significant tool to reduce the environmental impact of such technology. Preliminary results have been achieved on polypropylene-sepiolite systems by Prof. Camino group testing the materials by means of an oxygen consumption cone calorimeter apparatus; a reduction of the peak of the rate of heat released during combustion of 56% by adding 5 wt.% of pristine sepiolite was achieved [8].

Acknowledgement

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