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Life cycle assessment of three different management options for spent alkaline batteries

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ABSTRACT

The potential environmental impact of Landfilling, Incineration and Recycling of spent household alkaline batteries collected in continental Portugal was compared using LCA methodology and the Recipe Impact Assessment method. Major contributors and improvement opportunities for each system were identified and scenarios for 2012 and 2016 legislation targets were evaluated.

For 13 out of the 18 impact categories, the Recycling system is the worst alternative, Incineration is the worst option for 4 and Landfill is the worst option only for one impact category. However if additionally in each system the recovery of materials and energy is taken into account there is a noticeable advantage of the Recycling system for all the impact categories.

The environmental profiles for 2012 and 2016 scenarios (25% and 45% recycling rates, respectively) show the dominance of the Recycling system for most of the impact categories.

Based on the results of this study, it is questioned whether there are environmental benefits of recycling abroad the household alkaline batteries collected in continental Portugal and, since the low environmental performance of the Recycling system is particularly due to the international transport of the batteries to the recycling plant, is foreseen that a recycling facility located in Portugal, could bring a positive contribution to the environmental impact of the legislation compliance.

1. Introduction

The European legislation regarding waste is based on Framework Directive, Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008, that "lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use" (Official Journal of the European Union, 2008).

This Directive provides in Article 4 that the traditional waste hierarchy "shall apply as a priority order in waste prevention and management legislation and policy", and that when applying such hierarchy, "Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste" (Official Journal of the European Union, 2008). Thus, although recycling is a hierarchically preferential option than energy recovery or landfilling it is important to know, for certain waste flows, the environmental loads associated with the different options to assess whether it is environmentally advantageous to comply with that hierarchy. In the environmental impact analysis of these options, it should be considered not only the treatment processes itself (recycling, incineration and landfilling) but also all other implications of those, such the transportation, the production of energy and auxiliary materials, etc., thus, applying the life cycle perspective to such analysis, i.e. analyzing the environmental impact from the origin of the waste to its final disposal or until the products resulting from its treatment are an integral part of the environment.

For some wastes, such as for alkaline batteries, that are part of the waste flow of batteries and accumulators, additional reasons motivate and justify this kind of assessment: (1) The flow of waste batteries and accumulators includes a wide range of products both in structural terms – from button batteries to industrial batteries – and in composition and hazards to the environment of their constituents – from the alkaline and zinc carbon batteries, considered low-polluting until those that contain substances with recognized negative effect on the environment such as Mercury, Lead and

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Cadmium (Commission of the European Communities, 2003). The mandatory collection and recycling rates provided under current legislation (minimum of 25% by 2012 and 45% by 2016) applies to all portable batteries (and not just to those classified as hazardous as it was in previous legislation) not due to their hazards or potential environmental impact but because the collection schemes for all portable batteries have proven to be more efficient than separate ones for certain types of batteries, because consumers have shown difficulty in identifying and thus to separate the non-hazardous and hazardous batteries. (2) Moreover, despite being defined European targets for separate collection and recycling of all types of portable batteries (Official Journal of the European Union, 2006), that includes alkaline batteries, the batteries that are not separately collected will be sent for incineration or landfilling. The literature refers situations where, although the batteries were separately collected, they were sent to landfill, as happened at least in Sweden and Germany (Commission of the European Communities, 2003). In compliance with the current legislation these situations should no longer be possible since it obliges that all batteries collected separately are recycled. (3) Additionally, in the justification of the *current legislation* in the field of batteries, it is recognized the lack of scientific knowledge, or at least specific data and in particular of LCA studies (Commission of the European Communities, 2003) that fully support the guidelines adopted.

The awareness of governs about the impact of management alternatives for spent batteries has led to quite extensive studies done in some European countries such as the United Kingdom (ERM, 2006), Belgium (Briffaerts et al., 2006, 2009) and the Netherlands (AOO, 2002a,b). The European Commission has also promoted the development of knowledge in this field (European Commission, 2009).

The ERM study arose after the adoption by the EU Council of Ministers, of the proposed directive on batteries and accumulators. It was commissioned by the UK Department for Environment, Food and Rural Affairs (Defra). The objective of the study is to inform about the costs and benefits of various options to implement, in the UK, the collection and recycling of portable batteries as provided in the draft directive. This study uses the LCA with a subsequent economic evaluation of battery management alternatives between 2006 and 2030. It shows that the increase of battery recycling is beneficial to the environment due to the recovery of metals; however, it is done at a significant financial cost when compared with the elimination. Additionally estimations show that the implementation of the proposed directive will result in a significant increase in battery waste management costs, but with some savings in financial costs if environmental and social aspects are quantified (ERM, 2006).

In the study from Briffaerts et al. (2006, 2009) two hydrometallurgical (Revabat and Revatech) and two pyrometallurgical (Batrec and Valdi) treatment scenarios are compared for an average composition of Belgian spent batteries. The impact assessment method Eco-indicator 1999 was used. According to the study, none of the treatment scenarios have a better or worse overall performance than the others. Each option has specific advantages and disadvantages.

A study was conducted in 2002 comparing the life cycle of four waste treatment options for batteries collected in the Netherlands (AOO, 2002a,b): Batrec, Valdi, Nedstaal (production of steel in electric arc furnace) and Zimaval (hydrometallurgical treatment that produces metallic zinc). The CML impact assessment method was used. The study concluded that Valdi and Batrec have a better performance than Nedstaal and Zimaval. For Valdi, the main environmental impact was due to mercury emissions because in 2002 the facility was not equipped with activated carbon filter (AOO, 2002a). For Batrec, the results were negatively influenced by the relatively high production of waste.

The study, sponsored by the European Commission (European Commission, 2009) is an excellent compilation of data and technical information about battery recycling.

Despite the existence of some studies in this area, their results may not be extrapolated from country to country or even from region to region not only due to the specificities of the processes, but also to the characteristics of the countries/regions in question, such as the electric matrix.

Thus, it seems justifiable and helpful an evaluation of the environmental burdens of management alternatives for spent alkaline batteries, the portable batteries most commonly used in Portugal, which is the objective of this work. The methodology chosen for this study is the Life Cycle Assessment according to ISO 14040 (ISO, 2006a) and ISO 14044 (ISO, 2006b) standards. The following description *fulfils the requirements of these standards with limits on extension and with some adaptations in structure requested by a scientific paper.*

2. Goal and scope definition

2.1. Goal definition

The reason for this study is to know the potential environmental impacts associated with three management alternatives for spent household alkaline batteries collected in continental Portugal with the following final destinations: (1) landfilling; (2) incineration and (3) recycling.

The results of the study and the information developed in its implementation (in particular the knowledge of the processes involved and the identification and quantification of associated inputs and outputs) have several applications from which we can highlight a few, explored in this paper. On one hand the study allows to compare the environmental performance of these three management alternatives taking into account various environmental issues, defined by the impact categories and the different compartments of the environment i.e. air, water and soil. On the other hand, it allows identifying the origin (at the inventory level) of the most significant environmental burdens and, consequently, the environmental advantages and disadvantages of each alternative thus allowing the identification and definition of improvement opportunities for each one. It was also possible to study two scenarios of spent alkaline batteries management in continental Portugal, considering legislation targets for batteries collection and recycling in 2012 and 2016, in which the three mentioned options coexist. The 2012 and 2016 scenarios consider respectively: (i) recycling – 25% and 45%; (ii) landfill – 56% and 41% and (iii) incineration – 19% and 14%. The recycling rates of 25% and 45% correspond to the limits set by the legislation in force (Xará et al., 2014).

This study is intended to all those interested in knowing the comparative potential environmental impact of the options studied, and in this particular to the members of the entities involved in the definition of environmental policies and the management of these wastes. It is also intended to all whom it may concern to know the environmental advantages and disadvantages (opportunities for improvement) of each alternative such as professionals involved in the different processes considered.

Since this study is part of a research project it is expected that the results are used in comparative statements for public disclosure, particularly in technical and scientific communications that implies, according to ISO 14040, specific requirements in its dissemination.