CLEAN TECHNOLOGIES FOR RECYCLING: A CASE STUDY ON AUTOMOTIVE BATTERIES IN BRAZIL

HELOISA V. DE MEDINA

Chercheur au **CETEM** -Centre de Technologie Minéral- en stage post doctorat au **CREIDD** – Centre d'Etudes Interdisciplinaires sur le Développement Durable – de l'**UTT** -Université de Technologie de Troyes- bénéficiant d'une bourse CAPES du Ministère de l'Education du Brésil.

Abstract

During the last decade product design were enlarged to cope with environmental requirements from materials selection to final assembly and disassembly for recycling. DFE, DFR, DFD (Design for Environment, Design for recycling and Design for Disassembly) are new designing approaches that incorporate the environment issues from the beginning of a product development. But recycling does not intrinsically prevent environmental impacts. For instance, regarding toxic materials such as heavy metals, lead, mercury, chrome and cadmium, new and clean technologies and sound recycling processes management are required avoiding extra environmental impacts. This is exactly the case or lead car batteries that claims for cleaner recycling processes and for technological innovation. In this way new technological trails leading to more efficient batteries, are suppose to have a great impact on recycling process in medium-term and even short-term.

Car batteries are recycled all over the world at different rates such at 90 % in European Union and at 50 % in less developed countries. In Brazil we do not have official data on batteries recycling but a case study made at CETEM by V. Trouche(1) under my supervision got to an estimated rate on an interval from 65 to 80 %. The mains propose of this article is to present the main results of this case study, highlighting the best environmental practices and giving additionally some insights on environmental and economical aspects of car batteries recycling in Brazil. This case study was conducted not only for its importance on Brazilian market, but also for clean technologies and sound recycling process management required in order to avoid extra environmental impacts from lead car batteries discharge.

Key words: batteries recycling; clean technologies; lead recycling technologies; new batteries generation.

1 INTRODUCTION

During the last decade product design were enlarged to cope with environmental requirements from materials selection to final assembly and disassembly for recycling. DFE, DFR, DFD (Design for Environment, Design for recycling and Design for Disassembly) are new designing approaches that incorporate the environment issues from the very beginning of a product development, during the design phase. The idea is to design products with the environment in mind, avoiding rather than controlling environmental impacts of those products during theirs role life, from cradle to grave, or from mining extraction to materials production to end of life products recycling to materials recovery.

In Europe, since October 2000 according to European Directive on ELV's recycling (2), car makers are supposed to be responsible for their vehicles from cradle to grave. That means that they have to close automotive materials life cycle loop. In fact the strategies adopted by North American and European companies regarding environmental requirements are similar and the way automobiles are being conceived and manufactured from now on is changing the label of this former essentially polluter product into an almost 100 % recyclable one and maybe soon available in zero emission version. But recycling does not intrinsically prevent environmental impacts. For instance, regarding toxic materials such as heavy metals, lead, mercury, chrome and cadmium, new and clean technologies and sound recycling processes management are required avoiding extra environmental impacts.

In this scenario the importance of lead batteries recycling is strongly linked to the environmental requirements in both senses claiming for cleaner recycling processes and for technological innovation, such as rechargeable batteries or long lasting batteries for electric or hybrid vehicles. In short new technological trails leading to more efficient batteries, are suppose to have a great impact on recycling process in medium-term and even short-term.

For ELP in general the major contribution to a sustainable recycling is required from automobile industry mainly from the electric and electronics car components which are the largest materials intensive manufacturing sector. Besides that the economic viability of ELV recycling depends on disassembling techniques and materials separation processes. Best disassembling practices and soundest methods on separation economically feasible are nowadays the most important challenger for engineers and designers.

For automobile industry, according to ACEA European Automobile Manufacturers Association (3) the factors that determine the recyclability of single materials and components include the purity of the recovered products, the market for the recovered products, the monetary value of the material, the cost of collection and transport, the cost of sorting, the cost of transformation into reusable material and the cost of disposing of any residual material.

This is exactly what DFR (Design for Recycling) practices are looking for: to provide an added value recycling condition to new products at the end of their life. DFR is a new concept of the design activity that incorporates materials recyclability from the very beginning of the product creation. So complex products like automobile has to be designed to be assembled and disassembled. In fact, nowadays materials and products are being redefined and designed according to the consumers' expectations, reaching to improve the engine performance as well as to rend new products technologically innovative and environmentally friendly. In this context materials selection is one of the key elements of DFR some times called eco-design. And the life cycle engineering is the technical expression of waste prevention approach. "Since the rise in awareness of global ecological problems, the emphasis in pollution-control policy for industry has shifted away from end-of-pipe treatments and controls to waste prevention at the source and life-cycle engineering of products." (4)

This article aims to present an overview of the main aspects of lead recycling from car batteries illustrated by a six months case study conducted, in 2003, under my supervision by Vincent Gilles Trouche a former scholarship that developed at CETEM his Projet de Fin d'Etudes (PFE) en Génie Productique, to INSA de Lyon. An alternative clean technology, the CX system process by engitec, is presented and discussed as well as the main economic aspects that represent the strengths and the weakness for future development of the lead recycling market in Brazil.

2. LEAD RECYCLING FROM LEAD-ACID BATTERIES

2.1 Background

The importance of lead recycling is strictly linked to the environmental requirements in both senses claiming for cleaner recycling processes and for technological innovation, such as rechargeable batteries, long lasting batteries for electric or hybrid vehicles. In short it demands new technological trails leading too much more efficient batteries. In between nickel, zinc oxide, titanium nitride, and lithium are in perspective for future developments for vehicle uses. In this context the design of new batteries and the materials selection criteria taking into account materials recyclability are suppose to have a great impact on recycling process in medium-term and even short-term. It means that the development of a new generation of batteries is catching up the principles of life-cycle engineering. Batteries are a good example of practical R&D of the so called eco-materials. "In the R&D of ecomaterials, the end application of the material is obviously of great importance. In the field of consumer materials, where great quantities are consumed daily, efforts focus mainly on finding substitutes for harmful substances to reduce the environmental burden during and after use, examples being materials for batteries, packing, soldering, painting." (4)

For the time being the lead remains the major substance for car batteries as well as for industrial uses. The largest use of lead in U. S. for instance, around 80%, goes to automotive and industrial lead-acid batteries, consisting of a polypropylene case, lead lugs, electrodes, plastics spacers between them, lead oxide paste and sulphuric acid (5). Scrap automotive batteries (lead-acid batteries) are the major source of secondary lead in Brazil as all over the world. For lead Brazil have no primary extraction since 1996 (1), and nevertheless we have had one of the biggest domestic's apparent consumption increased in the last two years as showed at Table 1 and Table 2.

Table 1:

Recent Primary and Secondary Production of Lead in Brazil

MINERALS	SPECIFICATIONS	1995	1998	2001
Lead	Primary Metal	13 958	-	-
	Secondary Metal	50 000	48 000	52 000

Source: DNPM, Mineral Summary 1996, 2000, 2002 Note: (-)Null

Table 2:

Apparent Consumption of Metallic Lead Products in Brazil

	1997	1998	1999	2000	2001
Production of secondary lead	53	48	52	52	52
Import	60,7	60	56	70,7	73,4
Consumption	113,7	108	108	122,7	125,4

Source: Trouche V. 2003 (estimate based on DNPM data)

ULAB (usage lead acid batteries) recycling has important environmental concerns such as the risk of water, soil and air contamination. ULABs are a hazardous waste for recycling proposes as well as final disposal. Additionally to lead, automotive batteries have also acids and other metals and minerals such as arsenic, antimony, tin, calcium - in suspension and solution. The lead (oxide and metallic) represents around 70% in car batteries' weight and that why it's so important to have sound technologies and processes to recovery it from ULAB.

The recycling industry for batteries to cope with environmental regulations have to deal with complex tasks such as handling with toxic materials from collecting to transportation up to dismantling and separation of a number of materials, avoiding extra contamination of soil, air or water throughout all these phases. In addition it is also a complex market that depends directly on many actors such as scrap dealers, brokes, dismantlers and smelters and indirectly has to deal with governmental and environmental agencies and so on and so forth....

Nevertheless, car batteries are recycled all over the world at different rates such at 95% in United States, 90 % in European Union and at 50 % in less developed countries. In Brazil we do not have official data but Trouche's study estimated this rate on an interval from 65 to 80 %, varying according to the region.

2.2 Technical Aspects of Lead Recycling

Technically lead from batteries can be recovered by pyrometallurgical refining or by hydrometallurgical process. Pyrometallurgical refining (on blast furnace and rotary furnace) is traditionally the most used process worldwide for both primary and secondary lead productions. Wernick and Themelis (1998) resumed the pyrometallurgical ordinary recycling process "At a typical recycling plant, batteries are crushed or sliced and separated into streams: lead materials (about 60% lead, 15% PbO_2 and 12% PbO_4) polypropylene scrap, and sulfuric acid. The lead–containing materials are smelted to produce lead bullion and a molten silicate solution containing all of the lead oxides. This slag by-product is smelted and reduced with carbonaceous material and fluxing agents in a lead blast furnace, similar to those used in the primary smelting of lead oxides. The low-lead slag in such furnaces is environmentally inert and is disposed in industrial landfills". Nevertheless monitoring and preventing the escape of dust and fume is crucial.

In Brazil a recent study (6) conducted by Chemical Institute of UFRJ (Federal University of Rio de Janeiro) and at the FIOCRUZ (Oswaldo Cruz Foundation) provided indicators of environmental pollution in areas adjacent to a source of stationary lead emission based on dust and air contamination. This study measured lead concentration in both the outdoor air and the household dust from houses located around a lead-acid battery repair shop. As a result over 50% of the air samples exceeded the standard limit (1.5 ug $Pb.m^{-3}$) (for more details see http://www.scielo.br). This situation occurred some years after a dozen of small smelters have been shut down by public environmental authorities, from 1995 and 1999, in the same region.

Actually in the recent years, pyrometallurgical process has been largely improved to cope with the environmental requirements as well as to face the challenger of hydrometallurgy alternative that avoids gas emissions. Wernick and Themelis also pointed out some of these innovations: “in another lead recycling process, used extensively in Europe; lead components are smelted at 1000° with coke breeze and sodium carbonate flux and iron filings, used to fix sulphur by forming an iron sulphide matte, in a short fuel-fired rotary furnace. It is reported that use of bulk oxygen and other innovations can increase the production capacity of such furnaces by 40%. The ISASMELT furnace process, used in Australia and South Korea; introduces lead materials with lump coal into a vertical reactor containing a slag bath. Air and oxygen are injected in this reactor that similar to the top blown BOF furnace used for steelmaking. During smelting, metallic lead containing less than 0.01 antimony settles in the bottom and is periodically tapped out of the furnace. When the upper slag layer in the reactor reaches a certain depth the slag is reduced from 40-60% lead and 5-6% qntimony, to 2-4% lead and less then 1% antimony by continous injection in the presence of coal. Most of the treated slag is then tapped out the reactor and the cycle repeats. Thus, the two-reactor process used in U.S. (reverbatory and blast furnace) is replaced by a two stage process in a single reactor.” (5)

Hydrometallurgical methods are the newest and the soundest technology developed but its economic and industrial viability has to be proved. Hydrometallurgy is a chemical metal processing technology to dissolve a metal from its concentrate by using water, oxygen and other substances on a pressurised vessel. Usually there are a further series of chemical processes, involving a number of separation and purification steps, which result in the production of a high purity metal. Compared to the pyrometallurgy hydrometallurgy process is technically more efficient (recovers a higher percentage of the metal concentrated) more environmentally friendly and uses much less energy. On the other hand economically speaking its industrial scale is over 10 times smaller than the conventional pyrometallurgical smelters plants. Nevertheless **Engitec Technologies** presents its CX Compact process that is able to treat 5t/h batteries as and advantage compared to their CX traditional system.

The first steps on this via were made by **US Bureau of Mines** by the end of the 70's and the first results were published in 1981. At industrial level the best initiatives were provided by **Engitec Technologies** in 1992 (CX-EW and next the CX compact). The CX plants in operation are considered as state of art units for environmentally friendly design, for the quality of the recovered products and for the quality of design and manufacture of the equipment. As described by **Engitec** the CX systems plants were environmentally friendly designed, for the quality of the recovered products and for the quality of design and manufacture of the equipment. For instance in all units operating around the world the process water is continuously recycled. The main advantages of the CX Compact according to **Engitec** are:

- Minimizing the requirements for civil works and costs (can be pre-assembled)
- It can be easily transported
- Long life are guaranteed by stainless steel equipment
- As well as high performance and low maintenance costs
- It can be expanded (even at a later stage)

Engitec Technologies SpA is an engineering and contracting company, located in Milan, Italy, and active in the non-ferrous metals production. It is in charge of the design and construction of plants and complete facilities for the recycling of non-ferrous metal scraps and residues. (for further information see details at http://www.engitec.com or email info@engitec.com).

In Brazil, CETEM carried out a 5 five year research on recycling domestic batteries and automotive batteries. The aim of the first project was to determine the level of contamination of final disposal of domestic batteries on proper conditions. The second one aimed to reduce the environmental impacts of the pyrometallurgical process by associating a hydrometallurgical phase for lead paste desulphurisation from car batteries. (7)

These research at CETEM were encourage by CONAMA's Resolutions on batteries final disposal and recycling, by the end of the ninths (228/97, 235/98, 257/99) inspired on the 1994 Basel Convention (8) the ban of exports of hazardous waste (including ULAB) from developed to developing countries.

The photos, that we got from one of the greatest Tires and Batteries Collection and Transportation Company - Mazola Pneus, show how Brazil is nowadays transporting and packing ULAB according to Basel convention recommendantions. (see more detailed information at http://mazolapneus.com.br)

Source : Mazola, São Paulo, Brazil.

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3. ENVIRONMENTAL AND ECONOMICAL ASPECTS OF LEAD RECYCLING MARKET IN BRAZIL

The more restrict environmental regulations and the continuous falling down of international metallic lead prices through the lead recycling sector in Brazil into the ever present crisis. After 1995 most of lead recycler companies were shut down (a dozen of them in Rio de Janeiro) and the ones that remain are operating at a very low production scale. Some of them were shut down after 1995 by Environmental Federal Authorities under the pressure of the NGOs. Other were close down for financial and economic reasons such as over capacity and lack of suppliers such as Cobrac a primary lead producer, shut down in 1995 due to the depletion of mineral reserves. Among the most important ones we can mention:

FAE an independent one that had 2 industrial plants (São Paulo and Rio Grande do Sul) with an annual capacity of 24.000 tons, and **Saturnia - Microlite** a vertically integrated Co with a capacity of 18000 tons per year. (9)

Tonolli for instance is an independent recycler in São Paulo State with a capacity of 36.000 t. /year but actually produced around 12.000 in the year of 2001.

Moura is an integrated company (batteries and lead recycle) is located in Pernambuco State Northeast of Brazil, with a capacity of 22.000 t. per year

Tamara Metais is an independent company for metals recycling located at The State of Parana producing 12.000 tons per year.

Sulina de Metais located at the State of Rio Grande do Sul with annual production of 11.000 tons. (9)

Nowadays the Brazilian Lead Recycling Market is passing through a risk situation in both senses economic and environmental. There are a number of informal lead smelters and even some big companies, which are operating under risky situations. (10) Recent Greenpeace investigations, for example, revealed that Moura, one of the largest manufactures of car batteries in Brazil, is still importing ULAB.

For automotive batteries the national scenario also includes some important threats concerning the sound management practices requirements for recycling activities in Brazil such as:

- The lack of a National Programme for collection vehicles batteries, as we have for the aluminium cans.
- The large number of irregular final disposals at 90% of the Brazilian municipalities, mainly at the Northeast, North and Central regions.
- The environmental legislation is not enforced by an effective system at local level;
- The out-dated recycling technology based on pyrometallurgy processes

In a short run perspective the over capacity of Brazilian Batteries Producers and Recyclers associated at the depletion of the mineral reserves can be taken as opportunities to a enhancing the development of lead recycling sector.

From a medium or long-term perspective the following factors can be considered as the main challenges to a national policy for a sound recycling management:

- to improve the collection system organisation at local and national level
- To minimise waste transportation since it represents a high cost due to Brazilian geographic dimension
- To promote materials, product and process development towards cleaner recycling technologies
- To extend the polluter-pays principal to product manufactures concerning end of life products responsibility.

4. FINAL REMARKS

Broadly speaking DFE and DFR practices is surely a great opportunity for less developed countries' to get into the Research, Development and Designing of materials and manufactured products, which up to now concerned only the headquarters bureau employees. Because environmental impacts are a global concern that has no national frontiers and that calls for partnership and sharing different knowledge. In a word innovative solutions for clean products it's about team work. It also can drive all actors to global commitment towards the sustainability of mining, materials and industrial production. Working in network as partners they can share risks and profits and also get more innovative solutions to improve the recyclability of ELP on technical, economic and environmental bases.

Briefly we can say by our experience on this case study that life recycling for sustainability is a great challenge that means not only extending natural resources lifetime, reducing costs and wastes, and enforcing energy conservation; but also demands great effort on protection of human health and environment cares, clean materials recovery techniques development, well-organized collection systems establishing, and large markets for recycled materials assurance.

5. SUMMARY

This paper presents a case study on car batteries recycling and the technical process to lead recovery. It also compares the pyrometallurgical and the hydrometallurgical processes highlighting the best environmental practices. And ends by an overview of Brazilian market of car batteries recycling.

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