RECYCLING USED LEAD ACID BATTERIES

Introduction

Batteries are used whenever electrical energy is needed but there is no direct connection to the public electricity grid. A battery can convert chemical energy directly to electrical energy. Depending on the battery system, this converting process is irreversible or reversible. When the process is irreversible, the battery is called a primary battery. The reversible batteries are called secondary batteries and can be recharged up to 1000 cycles (i.e. lead acid battery-checken). A lead acid battery is rechargeable and is commonly used as a result of its good properties like low maintenance and suitable for many purposes. Furthermore they are easily available and are relatively cheap.

Lead-acid batteries either start or power cars, trucks, buses, boats and trains all over the world. This usage is well known but during the last years another usage is increasing. Solar panels are becoming cheaper and an enormous boost is seen in the adaption of solar applications in rural areas in developing countries where no electrical grid is available. As lead acid batteries are still the cheapest way to store energy, almost all these solar applications contain a lead acid battery.

However, lead is a very toxic metal and once the battery is not useful anymore, it is of the utmost importance that proper collection and recycling takes place. In order to effectively understand the issues about lead acid batteries in the solid waste stream and the benefits of diverting them to recycling, it is important to know some technical aspects of the lead acid battery, the public health and environmental risks associated with disposing of them, recycling methods and relevant legislation developed to minimize risks involved with the use and recycling.

Technical aspects

Lead Acid Battery cells consist of a lead (Pb) electrode and a lead oxide (PbO_2) electrode immersed in a solution of water and sulphuric acid (H_2SO_4). When the battery is connected to a load and energy is generated, the lead combines with the sulphuric acid to create lead sulphate ($PbSO_4$), and the lead oxide combines with hydrogen and sulphuric acid to create lead sulphate and water (H_2O). As the battery discharges, the lead sulphate builds up on the electrodes, and the water builds up in the sulphuric acid solution. When the battery is charged, the process reverses, with the lead sulphate combining with water to build up lead and lead oxide on the electrodes (source: www.gravitaexim.com).

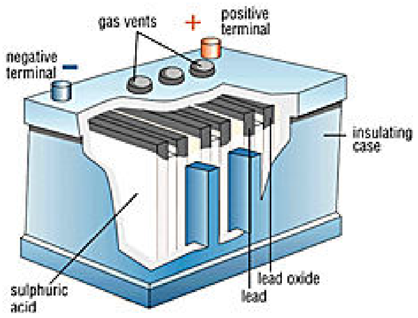

Figure 1: Example of a lead acid battery

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Generally there are two types of Lead-acid storage batteries, based on their method of construction: flooded or sealed. Flooded (or wet) lead acid batteries are those where the electrodes/plates are immersed in electrolyte and regular refilling with water is necessary to safeguard proper activity. In a sealed lead acid or valve-regulated Lead acid (VRLA) battery the electrolyte is immobilized. All lead acid batteries produce hydrogen and oxygen gas (gassing) at the electrodes during charging through a process called electrolysis. These gases are allowed to escape a flooded cell, however the sealed cell is constructed so that the gases are contained and recombined.

The grid structure in both batteries is made from a lead alloy. A pure lead grid structure is not strong enough and therefore other metals like antimony, calcium, tin, and selenium in small quantities are alloyed for added strength and improved electrical properties.

Lifetime
The battery lifetime is defined as the period of time in which a battery is capable of being recharged and retain the charge applied. Once the battery is no longer capable of being recharged or cannot retain its charge properly, its lifetime reaches its end and it becomes a `used battery` for the application it was designed for (UNEP, 2003).

The lifetime of a lead acid battery is very dependent on its rate, conditions and kind of use. It is estimated to be between 1 up to 5 years.

Composition
The typical lead acid battery comprises of: metal grids, electrode paste, Sulphuric acid, connectors and poles of lead alloy, and grid separators made up of PVC (see table 1). The battery components are contained in a corrosion and heat-resistant housing usually composed of plastic (polycarbonate, polypropylene, or polystyrene) (source: www.gravitaexim.com).

Component	[wt.-%]
Lead (alloy) components (grid, poles)	25 - 30
Electrode paste (fine particles of Lead oxide and Lead sulphate)	35 - 45
Sulphuric acid (10 - 20 % H_2SO_4)	10 - 15
Polypropylene	5 - 8
Other plastics (PVC, PE, etc.)	4 - 7
Ebonite	1 - 3
Others materials (glass, etc.)	< 0.5

Table 1: Composition of typical lead acid battery scrap

Recycling
Returning used lead acid batteries to the recycling loop has a long tradition. Thanks to the compactness of the battery, its high lead proportion and relatively high metal prices, it has been worthwhile for consumers to return their own or collected car batteries to the scrap trade or secondary smelters. This is also the case in low-income countries and return rates of up to 80% can be achieved normally through an informal collection system of scrap dealers, secondary lead processors and consumers (Vest, 2002).

Why recycle lead acid batteries?
The benefits of recycling of lead acid batteries are numerous. Unless we recycle used batteries certain toxic components pose a potential risk to the environment and human health. Moreover recovering scrap batteries has the advantages that it is easier and much less

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energy intensive than producing new lead from ore (the production of recycled lead requires 35-40% of the energy needed to produce lead from ore.) Recycling also reduces dispersal of lead in the environment and conserves mineral resources for the future when done in a proper way (Thornton, 2001).

However recycling of used lead acid batteries according international guidelines is not a simple process which can be done in small scale enterprises. Certain measures need to be taken to prevent negative impact to people and environment. The processes involved in recycling of used lead acid batteries will be summarised below following the descriptions in the technical guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries (UNEP, 2003, http://www.basel.int/meetings/sbc/workdoc/techdocs.html).

Collection
Used acid lead batteries must be collected, transported and stored with proper care, in order to avoid adverse health effects and environmental contamination. Special measures need to be taken at collection points and batteries should NEVER be drained at collection points as no guarantee can be given for safe treatment of the sulphuric acid with all hazards involved with the drainage to health and environment.

The recycling technology
The recycling process can be divided into three major processes:

1. Battery breaking
2. Lead reduction
3. Lead refining.

Battery breaking
Batteries must always be drained before they enter the recycling process. They should only be drained to a purpose built effluent treatment plant so that the acid can be treated and neutralised. Next the batteries are broken in a hammer mill or another type of crushing machine. Manual battery breaking should be avoided due to the health and safety risks associated with this practice.

The pieces from the breaking process are placed in a tank, where the dissimilar densities of the materials cause some to sink (lead), some to float (hard rubber and plastic) and liquids to go into solution (battery acid). From here, the materials are separated and treated individually.

The plastic is cleaned and transported to a plastic recycler. The acid is neutralized.

Lead Reduction
The battery scrap obtained from the breaking process is a mixture of several substances: metallic lead, lead oxide, lead sulphate and other metals such as calcium, copper, antimony, arsenic, tin and sometimes silver. In order to isolate the metallic lead from this mixture, these materials are charged into a furnace together with appropriate fluxes & reductants, drosses, returning slags and process dusts for smelting. Off-gases from the smelting furnace are filtered and the dust collected is returned to the furnace. The metal tapped from the kiln is transferred to refining kettles and processed to produce commercial quality lead.

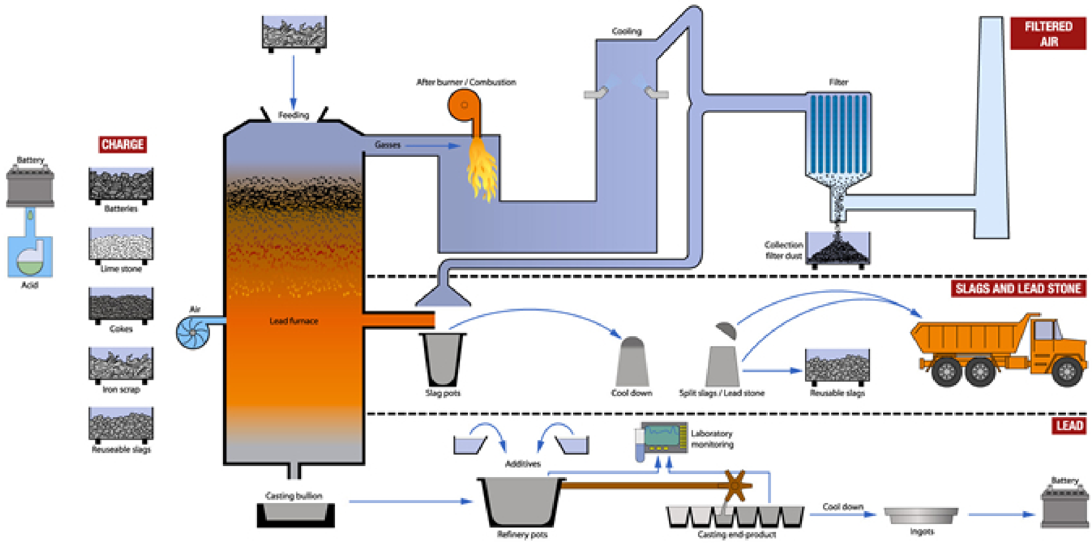

Figure 2: schematic drawing of the recycling process of lead acid batteries (source: www.campine.be)

Lead refining
As a smelting plant stops at the stage of the reduction plant, it will produce what is known as hard or antimonial lead. If the plant wants to produce soft lead, other metals like copper, antimony, arsenic and tin have to be removed. The refining process is applied in several steps in kettles with addition of specific agents. After this process the soft lead can be poured into moulds called "ingots". These ingots are sold on the local or international market.

Pollution control measures
In the recycling plant, effective control measures need to be implemented, both to protect the health of workers and to prevent pollution of the environment. Good plant design, with reduction of the potential for the emission of contaminating substances, is of utmost importance, and the newer smelting processes are inherently much cleaner than traditional blast furnaces. Pollution abatement technologies, including the treatment of exhaust gases and liquid effluents, need to be installed.

Those mostly exposed to releases within the plant are the workforce. Control measures such as maintaining minimum standards of air quality within the works, medical surveillance of employees, use of protective equipment, and provision of conditions of good hygiene in general, is necessary to avoid occupational lead exposure.

Health and environment
While using the lead acid battery for electricity, hazards exist during refilling of the flooded batteries. Harmful effects can occur during production and after its useful life, during recycling. At the end of its life the battery is classified as a hazardous waste under the Basel Convention and should be handled accordingly in order to prevent damage to human health or to the environment (UNEP, 2003).

Health
Lead is considered as one of the most toxic heavy metals. Its use is restricted and banned in some applications, like gasoline additives and tubes for drinking water (CE, 2000). Today, it is known that exposure to lead can cause adverse effects on many parts of the body. The organs potentially most affected are the brain and nervous system, kidneys, blood, and the reproductive system of both sexes. Lead in certain forms is also considered a possible carcinogen. Of particular concern is that relatively low levels can affect the developing foetus and young children, impairing their mental development and causing a small but measurable decrease in IQ. However, clinical symptoms are only found in very highly exposed individuals (who are usually exposed at work) and this is now extremely rare in the Western World (source: www.ila-lead.org).

Next to lead, also emissions of Antimony and Arsenic can take place which both are known as toxic substances. Furthermore Arsenic is known as carcinogenic (CE, 2000). *Sulfuric acid* is a highly corrosive acid which can destroy tissues of living organisms (UNEP, 2002).

Environment
The manufacturing as well as the recycling (smelting) of lead acid batteries can have negative impacts on the environment (Avellaneda de la Calle, 2002):

Air: Emission of lead (and other heavy metals) dust and fumes.
Soil: Spilling and leaking of acid from the batteries directly to the soil. Leaching of acid and lead salt due to improper processing.
Water: Spilling and leaking of acid to water surfaces. Direct dilution of lead salts in water or through rain water when present in soil.

These emissions can pollute the soil and poison the ground water with negative effects on the ecosystems (plants, animals, humans).

International legislation

As used lead acid batteries are regarded as hazardous waste, various laws, decrees and guidelines are developed on international and European level to deal with these materials. For used lead acid batteries often specific legislation is developed in combination with household batteries.

United Nations

On an international level the Basel convention is very important for both used lead acid batteries. Furthermore the Secretariat of the Basel Convention has set up guidelines for a safe treatment of used lead acid batteries.

Basel Convention (source: www.basel.int)
In March 1989, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, was adopted. The treaty entered into force in 1992. Drawing on the principles of *environmentally sound management*, the convention seeks to protect human health and the environment from the risk posed by hazardous wastes. This will require changing the economic equation for wastes in order to motivate the producers of hazardous wastes and people who benefit from the associated goods to take action. To do this, the convention sets out a three step strategy (UNEP 2002):

1. Minimizing the generation of wastes.
2. Treating wastes as near as possible to where they were generated.
3. Minimizing international movements of hazardous wastes.

Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries (source: www.basel.int)
These guidelines offer managers a set of best practices and principles for setting up effective systems for recycling batteries. They describe how to collect, transport and store used batteries; give specifications for the storage chambers and transport facilities; describe how batteries delivered to the recycling plant should be drained of their electrolytes, identified, segregated, and stored; explain how the recovered lead must be refined in order to remove unwanted contaminants; and address medical issues and public awareness. The Guidelines conclude that the most effective approach to collection is to rely on manufacturers, retailers, wholesalers and service stations to retain old batteries at the time new ones are provided to the customer.

European Union

The European Union wants less hazardous substances in batteries and wants to improve collection and recycling. Therefore a new directive was established in 2006:

Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators

The aim is to cut the amount of hazardous substances - in particular, mercury, cadmium and lead - dumped in the environment; this should be done by reducing the use of these substances in batteries and accumulators and by treating and re-using the amounts that are used (source: http://europa.eu/scadplus/leg/en/lvb/l21202.htm).

Conclusion

Recycling of lead acid batteries is not a simple activity which can be done in small enterprises. Constructing, commissioning and operating a modern environmentally sound recycling plant is a very expensive undertaking. Not only does the initial capital investment run into many millions of dollars, but there is an ongoing, and essential, cost overhead to cover environmental and hygiene control systems. Any modern recycling plant must have a constant and high throughput of used lead acid batteries. Local governments should focus on an environmentally safe collection of used lead acid batteries and delivery to an environmentally sound smelter, even if this means that used batteries have to be exported to achieve this goal.

References and further reading

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Useful addresses

Secretariat of the Basel Convention (SBC): International Environment House 15 Chemin des Anémones CH-1219 Chatelaine, Switzerland Tel: 4122 9178218 Fax: 4122 7973454 Email: sbc@unep.ch Web: www.basel.int Implements the program set out by the parties whose objective is "environmentally sound management" (ESM), the aim of which is to protect human health and the environment by minimizing hazardous waste production whenever possible. ESM means addressing the issue through an "integrated	The Blacksmith Institute 2014 5th Avenue New York, NY 10035 U.S.A. Phone: (646) 742-0200 Fax: (212) 779-8044 Email: info@blacksmithinstitute.org Web: www.blacksmithinstitute.org Blacksmith Institute's vision is a clean planet for our children. The Blacksmith Institute develops and implements sustainable solutions for pollution-related problems in the developing world. The Staff work cooperatively with partnerships of donors, governments, NGO's and others, and provide strategic, technical, and financial

life-cycle approach", which involves strong controls from the generation of a hazardous waste to its storage, transport, treatment, reuse, recycling, recovery and final disposal.	support to local champions as they strive to solve specific, pollution-related problems in their communities.
ILMC (The International Lead Management Center) 2525 Meridian Parkway, Suite 100 Research Triangle Park NC27713 USA Tel: ++1 919-287-1872 Fax: ++1 919-361-1957 Email: info@ilmc.org Web: www.ilmc.org International centre for advice on all aspects of lead risk management	ILA (International Lead Association) 17A Welbeck Way London W1G 9YJ UK Tel: +44(0)20 79356146 Fax: +44(0)20 74931555 Email: info@ila-lead.org Web: www.ila-lead.org Representation of the lead industry

Internet addresses

www.cwgnet.net iwebsite of the Collaborative Working Group on Solid Waste Management in Low- and Middle-Income Countries (the CWG). Has access to articles, conference proceedings, networking information, and a working group on the global informal sector in solid waste.

www.ilo.org iwebsite of the International Labour Organization. The UN specialized agency which seeks the promotion of social justice and internationally recognized human and labour rights.

www.iswa.org website of the International Solid Waste Management Association. ISWA publishes Waste Management World, www.waste-management-world.com

www.worldbank.org/solidwaste website of the World Bank. Contains, has a great deal of very good information on solid waste management in developing countries

This technical brief was updated by Sophie van den Berg, March 2009 for Practical Action.

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