Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

The recycling chain for used lead-acid batteries in Ghana

Observations and general considerations

Freiburg, May 2015

Authors

Andreas Manhart
Öko-Institut e.V.

Tobias Schleicher
Öko-Institut e.V.

Head Office Freiburg
P.O. Box 17 71
79017 Freiburg
Street address
Merzhauser Strasse 173
79100 Freiburg
Tel. +49 761 45295-0

Office Berlin
Schicklerstrasse 5-7
10179 Berlin
Tel. +49 30 405085-0

Office Darmstadt
Rheinstrasse 95
64295 Darmstadt
Tel. +49 6151 8191-0

info@oeko.de
www.oeko.de

Table of Contents

List of Figures

1. Introduction

The unsound recycling of lead-acid batteries can cause serious threats to human health and the environment. Due to the toxicity of lead and the sulfuric acid of the batteries, the recycling chain and the applied management practices require a high level of attention in order to prevent impacts such as massive lead contamination of soil and waterbodies as well as exposing of workers and neighboring communities.

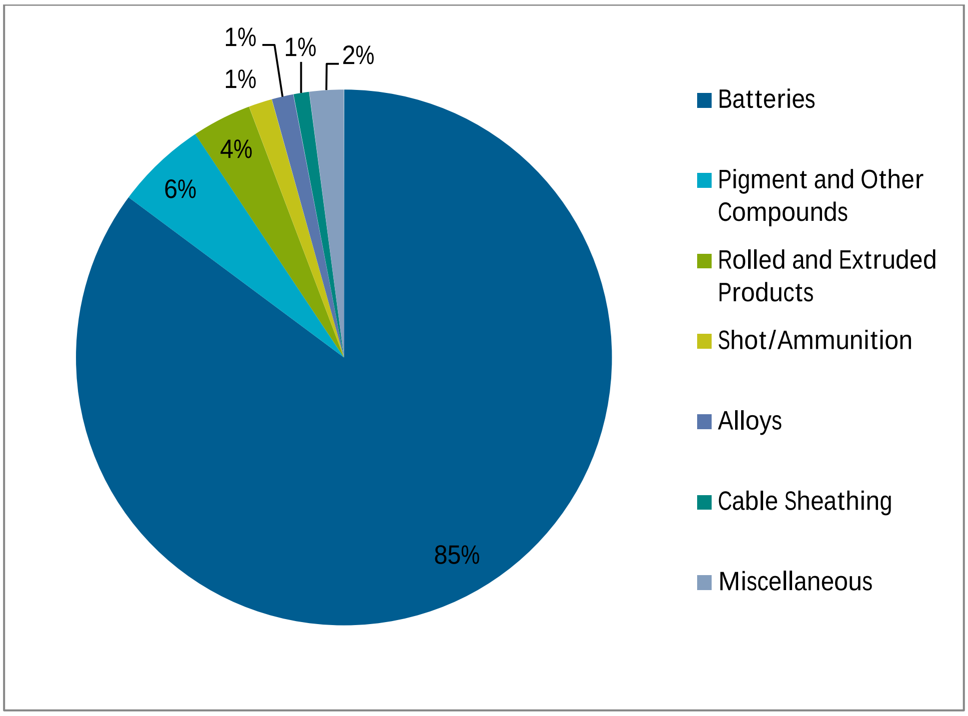
This paper provides some basic considerations on sources, management and downstream markets of used lead-acid batteries. The majority of information contained in this document was derived during various field studies on the lead-acid battery recycling chain in Ghana. Although the situation in Ghana cannot be extrapolated to other African countries, it seems plausible that some of the characteristics may be found also in other countries with comparable socio-economic situations.

Thus, the document is intended to support field investigations in developing countries and emerging economies by sharing core findings from Ghana as well as some general considerations on lead-acid battery recycling.

2. Sources of used lead-acid batteries

Batteries are by far the biggest application of lead. According to the International Lead Association 85.2% of the world lead is used to manufacture batteries (see Figure 2-1).

Figure 2-1: Principle uses of lead worldwide in 2012



Source: ILA 2015

With regards to lead as source of environmental and health concern, the following applications might also be relevant in some countries:

- Pigments and paints
- Tire balance weights[1]
- Weights for fishing nets and boats
- As additive to gasoline (in the form of tetra-ethyl lead)[2]
- Glass (e.g. cathode ray tubes of TVs and monitors)
- Ammunition

The vast majority of lead-acid batteries are starter batteries for conventional passenger vehicles and trucks. Nevertheless, there are two additional common applications of lead-acid batteries:

- Stationary electricity storage in conjunction with the use of decentralized electricity systems (e.g. solar power).
- Uninterruptible power supplies (either for the use together consumer devices such as personal computers, or in data centers and other critical infrastructure such as hospitals).

3. Design of lead-acid batteries

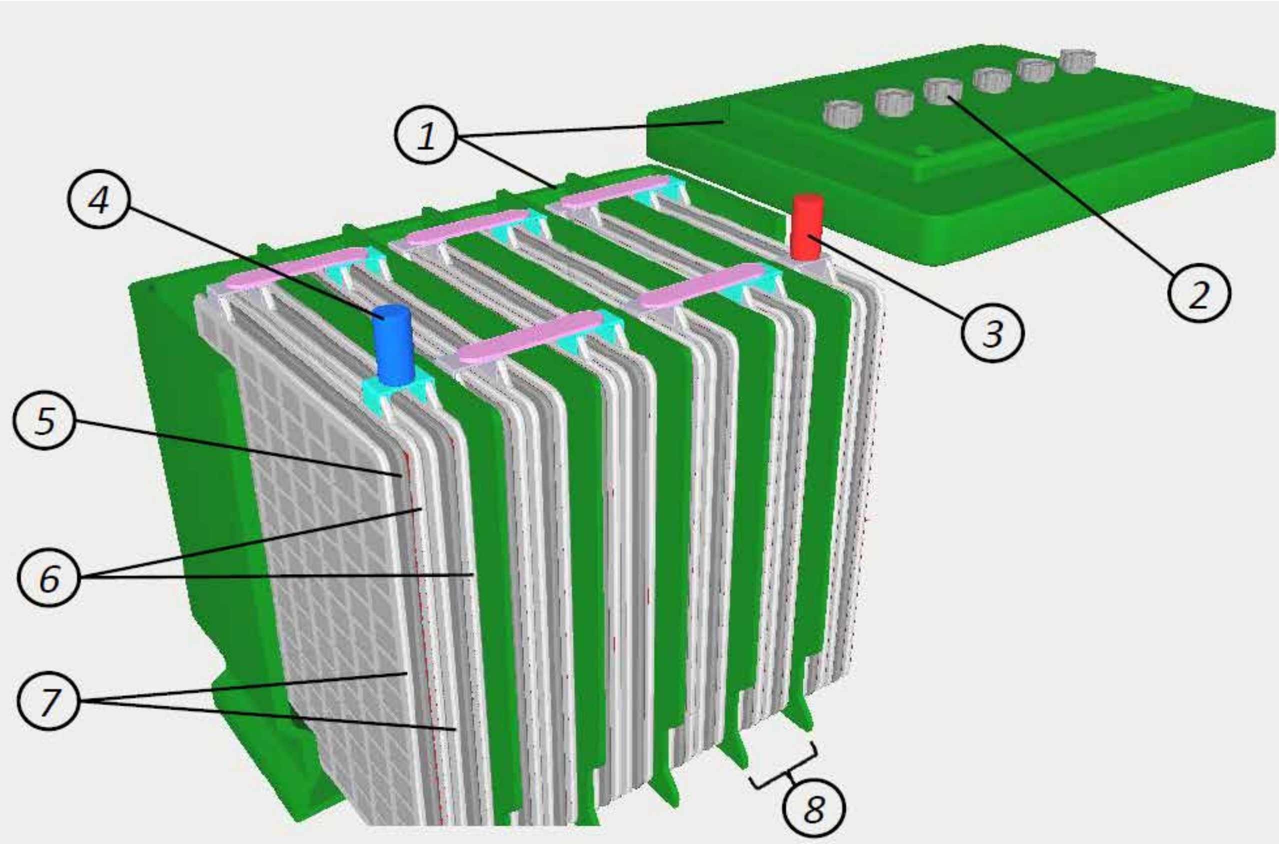
Most lead-acid batteries have a quite uniform design that is illustrated in Figure 3-1. Within each battery cell, positive plates (cathodes) made from lead-oxide (PbO_2) and negative plates (anodes) made from a lead-alloy are inserted in a sulfuric acid solution. Most commonly, the liquid consists of 35% sulfuric acid and 65% water (ILZSG 2013).

To avoid the contact of cathodes and anodes, the plates are separated by a non-conductive porous layer, mostly a grid of reinforced polyethylene (ILZSG 2013). The cathode plates are connected to the positive terminal (plus-pole), the anode plates to the negative terminal (minus-pole). Both, connectors and poles are mostly made from lead (possibly with alloying elements). The case is mostly made from polypropylene (PP). Some battery-types are equipped with plugs that can be opened to refill with distilled/deionized water if required. The plug also functions as escape route for oxygen and hydrogen gas that is formed in the cells (SBC 2003).

[1] In the EU lead-based tire balance weights are banned from all vehicles sold in the EU. As a consequence, most tire balance weights are today manufactured using other metals such as zinc or steel.

[2] The use of leaded fuel is phased-out in most countries.

Figure 3-1: Typical design of a lead-acid battery



1 = case 2 = plugs 3 = positive terminal 4 = negative terminal

5 = plate separators 6 = negative plates 7 = positive plates 8 = one battery element

Source: By KVDP [CC BY-SA 3.0], via Wikimedia Commons, modified by the authors

4. End-of-life management & recycling

Figure 4-1 gives a rough overview about the management and recycling chain as observed in Ghana. More details about the associated processes are given in the following sections. Generally, all recycling activities have to be linked to a market for secondary lead. Generally, the most important application for lead is the production of new lead-acid batteries (around 85% of the world lead production is used for this segment). Thus, in countries with no lead-acid battery production, recycling is

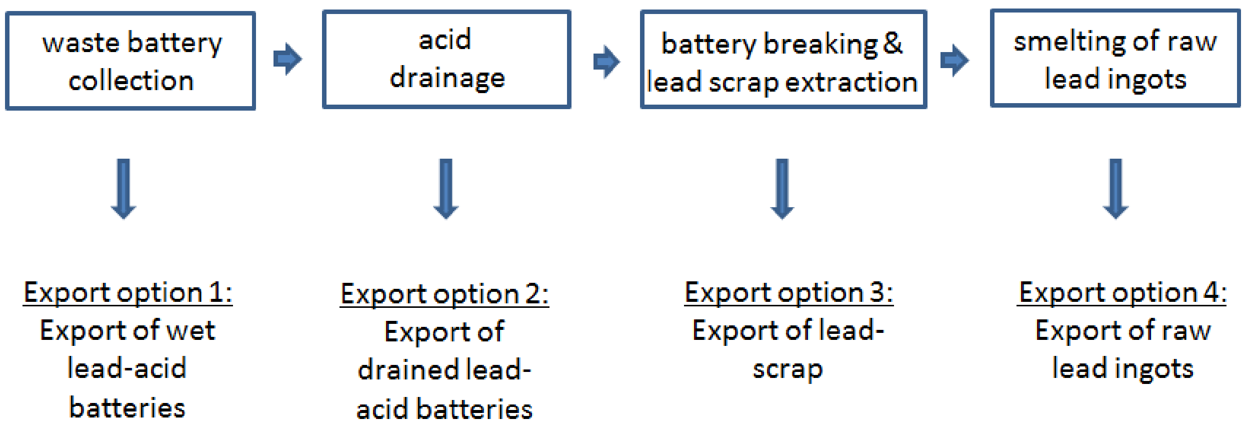
- either tied to alternative downstream markets for lead (e.g. to be used as weights for fishing nets, ammunition production),
- or has to be linked to foreign lead-processing.

As the first market option is mostly limited in terms of lead demand, most large scale recycling is somehow related to the international lead market.

Figure 4-1 illustrates the various possible links (handover points) to foreign recycling activities. In Ghana, all four export options exist in parallel. Here, it has to be mentioned that the export options

1-3 deal with hazardous waste so that all trans-boundary movements require a notification according to the Basel Convention[3]. If such a notification is non-existent, the export (and the corresponding import) has to be regarded as illegal. Here it needs to be noted that export option 4 – despite being legal without notification – is not necessarily beneficial in terms of environmental and human health impacts. In contrast, there are strong indications that export option 4 is possibly associated with the most severe local impacts.

Figure 4-1: Generic used lead-acid battery management paths for countries without lead-refinery



Source: Oeko-Institut e:V.

4.1. Collection

Due to its high lead-content, used lead-acid batteries are economically attractive for recycling. In Ghana, traders and recycling companies offer cash-money for used lead-acid battery deliveries. Therefore, there are many small and medium size companies and individuals active in collecting and selling used lead-acid batteries, often as a side-business. Generally, used lead-acid batteries are often accumulating in and around car-repair shops and clusters. Thus, car-repair companies often store used batteries from battery exchange services and sell them to small-scale scrap metal collectors (often referred to as ‘scavengers’), traders or even recycling companies (depending on the volume of collected batteries).

The export of wet lead-acid batteries for recycling (export option 1) is not practiced at large scale in Ghana. The only known efforts in this direction are the exports carried-out within the framework of the Best-of-two-worlds” project (Oeko-Institut 2014). These exports were in-line with all international standards in terms of packaging and notification.

[3] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal.

Figure 4-2: Wet lead-acid batteries for export (packed according to relevant international standards)

Source: Oeko-Institut e.V.

Nevertheless, a country might also receive wet lead acid battery imports from neighboring countries.

4.2. Reconditioning

Some of the collected batteries might undergo reconditioning practices in order to produce and sell functioning second hand batteries to the local market. These reconditioning practices are typically carried out in small workshops with not much attention to prevent acid and lead emissions (Partner in Development 2009).

The most basic form of reconditioning is to top up the batteries with water / electrolyte and to recharge the battery. More sophisticated reconditioning also includes the opening of the case and the exchange of failed cells. It is assumed that this type of reconditioning mostly leads to quite limited battery life-time extension (Partner in Development 2009).

4.3. Acid drainage

Some persons involved in collection and transport of lead-acid batteries drain the contained acid prior to transport by opening the plugs or by punching holes into the case (in Ghana, the battery-acid is commonly referred to as 'water'). This is mostly done to reduce the weight of the battery[4], but also because buyers often only pay for drained batteries, or give price-deductions for un-drained batteries.

While many batteries are already drained before transport to trading hubs, others are drained at a later stage in the management chain (e.g. on scrap metal markets or within battery recycling facilities).

This practice of uncontrolled acid drainage is the first major point of pollution. In addition to the acid emissions and the related environmental impacts and potential health consequences, also dissolved lead and lead-particles are commonly spilled-out together with the acid.

In Ghana, some traders export drained lead-acid batteries for recycling. In the past, such exports were granted notification from the Ghanaian authorities. In 2013, the authorities stopped issuing notifications for exports of drained batteries. It is not known whether drained batteries are exported without notification.

4.4. Battery breaking & lead scrap extraction

In order to extract the lead scrap, batteries are manually broken, mostly by using machetes. The process is mostly associated with massive emissions of lead, lead-dust and remaining acid as it is often carried out on unsealed ground and without any precautions to avoid emissions.

[4] The acid makes-up around 10-15% of the total battery weight.

Figure 4-3: Opening of drained lead-acid batteries to extract lead-scrap

Source: Bo2W-Project

Aside from lead, the process also yields plastic cases, which might be recycled in local plastic industries[5]. Open and empty battery cases are therefore an indication that battery breaking is carried-out within an area (see Figure 4-4).

5 In case the plastic is sold to the plastics recycling industries, cross-contamination might be a problem. Even if washed with water, it is likely that the secondary plastics will continue to be contaminated with up to 5% of lead. Thus, recycling of the plastic case requires at least two washing cycles, with the second one preferably with an alkaline solution (SBC 2003).

Figure 4-4: Empty battery-cases as indication that battery breaking is conducted

Source: Oeko-Institut e.V.

While the extracted lead might be directly passed-on to smelting (see section 4.5), some businesses also export the lead scrap to foreign lead smelters and/or refiners (export option 3).

4.5. Smelting of raw lead ingots

The lead scrap retrieved during the battery breaking (see section 4.4) is often melted into raw lead ingots. Generally, this is either carried-out in small backyard processes (see section 4.5.1), or in large smelters using installed industrial furnaces (see section 4.5.2). Both processes generate raw lead ingots. While industrial secondary lead smelting can achieve purities of up to 97-99%, ingots from backyard smelting still contain considerable amounts of lead-oxide. Both types of ingots also contain other impurities such as tin, antimony and other metals. In order to be used for the manufacturing of new products (e.g. new lead-acid batteries), such ingots have to be shipped to refineries that can produce standardized lead with a purity of 99.97%.

While industrial lead-smelting can be carried-out without significant emissions of lead, many low standard facilities in developing countries and emerging economies should be regarded critical in this regard. Together with informal lead smelting, the process is ranked as the worst polluting practices in the world (Blacksmith Institute 2012).

4.5.1. Backyard lead smelting

As lead smelting does not require very hot temperatures (melting point of lead = 327.46°C), lead-smelting can be carried-out without big investments and by using simple tools such as melting pots over open fires. In contrast to industrial secondary lead smelting (see section 4.5.2), the process does not reduce lead-oxide into elementary lead. Therefore, backyard lead smelters often sort out the cathode-plates - that are made from lead dioxide - prior to smelting.

Generally, the process is quite simple: The lead-scrap is melted in a melting pot over a fire. The liquid metal is poured into a casting mold. After cooling, the raw lead ingot is freed from the mold (see Figure 4-5). The raw lead ingots are exported to refineries for the production of pure lead (99.97% purity).

Figure 4-5: Backyard lead smelting

Source: Oeko-Institut e.V.

The process is quite critical because of its emissions of lead in solid form (e.g. dust) as well as the lead fumes during smelting. In Dakar (Senegal), such informal lead smelting exposed total number of 40,000 people to lead dust and caused the death of 18 children under the age of five in 2008[6] (Blacksmith Institute 2012).

6 The lead emissions where not only caused by the smelting itself, but also by the acid drainage and battery breaking.

4.5.2. Industrial secondary lead smelting

Industrial secondary lead smelting can be carried-out with various types of furnaces: blast furnaces, reverberatory furnaces, electric arc furnaces and rotary furnaces. The two most commonly used types of furnaces – the blast and rotary furnaces – are displayed in Figure 4-6. Both types of furnaces are fueled by combustion fuels such as charcoal. Within the furnaces, metallic lead is melted and lead-oxide is reduced to elementary lead. Some impurities might be removed with the slag-phase. The lead is casted into ingots, which are supplied to lead refineries (export necessary).

Both types of smelters are usually equipped with dust collection and air filtration to capture lead-containing dust emissions. Generally, dust emissions are a severe source of lead contamination for surrounding communities. There are various types of filters, including bag filters, electrostatic precipitators, cyclones, ceramic filters and scrubbers (SBC 2003). Collected filter dust is either re-processed in a plant's furnace or (if the furnaces are not capable of treating filter dust) shipped to other smelters for treatment. Generally, off-gas dust and filter dust contains high concentrations of lead and is potentially a severe source of pollution.

Figure 4-6: Two major types of secondary lead furnaces: Blast furnace (left), rotary furnace (right)

Source: Oeko-Institut e.V.

5. Summary

There are various types of recycling practices and business models for used lead-acid batteries established in Ghana. The domestic market for lead is considered to be quite limited in terms of total lead consumption and most likely only related to the manufacturing of weights for boats and fishing nets and the (illegal) production of weapons and ammunition. Therefore, all bulk recycling of lead-acid batteries is tied to international lead markets.

Lead is either exported as part of batteries (export of wet or drained lead-acid batteries), as lead scrap, or as raw lead ingots. All export options have in common that the lead needs to undergo further refining before being used in industrial production (e.g. the manufacturing of new lead-acid batteries). Therefore, the exports have to be linked to lead refineries producing lead-ingots and alloys of defined composition and purity.

As 85% of the world lead production is used for the manufacturing of lead-acid batteries, the observed recycling practices are with a very high probability integral part of the supply-chain of lead-acid battery containing products, mostly motor vehicles.

Most observed management practices for lead-acid batteries in Ghana have severe impacts on human health and the environment. To date, only the exports of wet lead-acid batteries that were carried-out under the Best-of-two-worlds project can be regarded as environmentally sound management (see section 4.1). Cases from Senegal (Haefliger et al. 2009) and Kenia (Benards & Abraham 2012), as well as oversight studies as conducted by the Blacksmith Institute (2012) suggest that unsound lead-acid battery recycling severely endangers the health of workers as well as local communities.

List of References

Benards & Abraham 2012	Benards, O.; Abraham, W.: Lead Poisoning in Owino Uhuru Slums in Mombasa – Kenya. Internet: http://www.cofek.co.ke/Lead%20Poisoning%20in%20Owino%20Uhuru%20Slums%20Mombasa.pdf (retrieved: 20.05.2015).
Blacksmith Institute 2012	Blacksmith Institute & Green Cross: The World's Worst Polluting Problems: Assessing Health Risks at Hazardous Waste Sites. Internet: http://www.blacksmithinstitute.org/senegal-lead-poisoning-and-car-batteries-project.html
Haefliger et al. 2009	Haefliger, P.; Mathieu-Nolf, M.; Lociciro, S.; Ndiaye, C. ; Coly, M. ; Diouf, A. ; Faye, A.L. ; Sow, A. ; Tempowski, J.; Pronczuk, J.; Junior, A.P.F.; Bertollini, R.; Neira, M.; Mass Lead Intoxification from Informal Used Lead-Acid Battery Recycling in Dakar, Senegal. In: Environmental Health Perspectives, 117(10): 1535-1540.
ILA 2015	International Lead Association: Lead facts. Internet: http://www.ila-lead.org/lead-facts (retrieved: 12.03.2015).
ILZSG 2013	International Lead and Zinc Study Group: Design of Lead Acid Batteries for Recycling. ILZSG Secretariat Briefing Paper No. 37, Lisboa, 2013.
Oeko-Institut 2014	Oeko-Institut e.V.: Lead-acid batteries from Ghana successfully recycled. Press release from 11.03.2014. Internet: http://www.oeko.de/en/press/press-releases/archive-press-releases/2014/lead-acid-batteries-from-ghana-successfully-recycled/ (retrieved: 17.03.2015).
Partner in Development 2009	Partner in Development: Solar energy projects in Ghana; How to handle lead acid batteries after their useful life? Schipluiden, 2009.
SBC 2003	Secretariat of the Basel Convention: Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries. Geneva, 2003.