ENVIRONMENTALLY SOUND MANAGEMENT OF SPENT LEAD-ACID BATTERIES in North America

Technical Guidelines

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Technical Guidelines

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List of Abbreviations and Acronyms

ABR	Association of Battery Recyclers
AL	*action level*
BCI	Battery Council International
BLL	blood lead level
BOD	biochemical oxygen demand
CCME	Canadian Council of Ministers of the Environment
CEC	*Commission for Environmental Cooperation*
COD	chemical oxygen demand
DOT	Department of Transportation (US)
EH&SMS	*environmental, health and safety management system*
ENGO	environmental nongovernmental organization
EPA	Environmental Protection Agency (US)
ESM	environmentally sound management
ESP	electrostatic precipitators
HEPA	high efficiency particulate air
ISO	*International Standards Organization*
$Mg(OH)_2$	*magnesium hydroxide*
LABs	lead-acid batteries
LGPGIR	Ley General para la Prevención y Gestión Integral de los Residuos (General Law for the Prevention and Management of Waste)
Li-ion	lithium-ion
NAAEC	North American Agreement on Environmental Cooperation
NAFTA	North American Free Trade Agreement
NIOSH	National Institute for Occupational Safety and Health
NiCd	nickel cadmium
NGO	nongovernmental organization
NOM	Norma Oficial Mexicana (Official Mexican Standard)
NO_x	nitrogen oxides
OSHA	Occupational Safety and Health Administration
PbO	lead oxide
PbO_2	lead dioxide
PEL	permissible exposure level
PE	*polyethylene*
POI	*point of impingement*
PPE	personal protective equipment
Profepa	Procuraduría Federal de Protección al Ambiente (Federal Attorney for Environmental Protection) (Mexico)
PVC	polyvinyl chloride
Semarnat	Secretaría de Medio Ambiente, Recursos Naturales y Pesca (Ministry of the Environment, Natural Resources and Fishing—Mexico)
SLABs	spent lead-acid batteries
SO_2	sulfur dioxide
SQG	Soil Quality Guidelines (Canada)
TDS	total dissolved solids
TRC	total reference concentration
TSS	total suspended solids
TWA	time-weighted average
VOC	volatile organic compound
WESP	wet electrostatic precipitator

Abstract

Given the ongoing and shared interest among Canada, Mexico and the United States to foster environmentally sound management (ESM) in the recycling of spent lead-acid batteries (SLABs), in 2014 the Commission for Environmental Cooperation (CEC) of North America began the development of technical guidelines on ESM practices for secondary lead smelters and other facilities that process SLABs.

As part of the guideline development process, the CEC Secretariat solicited feedback from SLAB recyclers and other potential stakeholder groups and technical experts in all three countries that could provide useful input on various aspects of ESM practices and technologies for SLAB recycling. To achieve this, a consultation workshop was held in Mexico City in October 2014. Over 100 participants attended, including leading experts in industry, government, and nongovernmental organizations (NGOs) of Canada, Mexico and the United States. In addition, two public reviews were conducted to gather comments on the various versions of the draft guidelines. All suggestions and feedback received were reviewed and used as a base to revise and adjust the guidelines.

These guidelines identify and consolidate best practices and technologies for recycling SLABs in a manner that protects the environment, health, and safety of workers and the public. They also provide recommendations on how to implement ESM practices and technologies within new and existing SLAB collection, storage and recycling facilities that operate in North America.

Executive Summary

When carried out properly, the recycling of spent lead-acid batteries (SLABs) can be an environmental success story. In addition to diverting batteries from disposal and reducing the need to mine for new lead, the recycling of SLABs provides a critical and stable supply of secondary lead to the battery industry. Improper lead-acid battery recycling practices, on the other hand, can result in serious, long-lasting harm to workers, communities and the environment.

Given the ongoing and shared interest among Canada, Mexico and the United States to foster environmentally sound management (ESM) in the recycling of SLABs, in 2014 the Commission for Environmental Cooperation (CEC) of North America commissioned the development of technical guidelines on ESM practices for secondary lead smelters and other facilities that process SLABs. These guidelines identify and consolidate best practices and technologies for collecting and recycling SLABs in a manner that protects the environment, health, and safety of workers and the public. They also provide recommendations on how to implement best practices and technologies within new and existing SLAB collection, storage and recycling facilities that operate in North America.

As part of the guideline development process, the CEC Secretariat solicited feedback from SLAB recyclers and other relevant potential stakeholder groups and technical experts in all three countries that could provide useful input on various aspects, best practices, and technologies for inclusion in the technical guidelines. To achieve this, a consultation workshop was held in Mexico City, Mexico, in October 2014. Topics included SLAB collection, storage, transportation and recycling, and associated ESM considerations. More than 100 participants attended the workshop, including leading industry, government, and nongovernmental organization (NGO) experts from Canada, Mexico and the United States. All comments and feedback received were reviewed and used to revise and adjust the guidelines, based on research of the validity of the suggested changes.

The technical guidelines are divided into seven key sections:

Section 1 explains the background and context of the project, the rationale for the project, the objectives and scope of the project, and the organization of the report.

Section 2 begins by offering a high-level overview of the economics of SLAB recycling and the consolidation of the industry in North America. It lays out the various components of a lead-acid battery, including typical lead content and lifespans, and provides a short introduction into the SLAB recycling process.

Issues surrounding the collection, transportation and storage of SLABs—which together make up the pre-recycling process—are discussed in Section 3. This section explores the differences in how the collection infrastructure works in Canada, Mexico and the United States, and identifies the key players in the SLAB supply chain. Furthermore, environmental and safety hazards that can arise during the collection, storage and transportation of SLABs, as well as ESM practices that should be implemented to address them, are identified and recommended. This includes, for example, proper packaging of SLABs for shipment, and ensuring that non-lead batteries (e.g., lithium-ion batteries) do not enter the SLAB processing stream. The section concludes with an overview of ESM practices for the temporary storage of SLABs at collection centers; management of leaking spent acid electrolyte from damaged batteries; and SLAB-storage building requirements.

Following the presentation of ESM practices for the collection, transportation and storage of SLABs is a discussion on the various stages in the SLAB recycling process and the ESM considerations that should be taken into account at each step. After describing each of the steps in the SLAB recycling process—battery breaking, lead reduction, and lead refining—in detail, Section 4 identifies the key environmental and safety hazards associated with each activity and offers recommendations on ESM practices that should be considered for implementation.

Section 5 addresses ESM approaches to pollution control at SLAB recycling facilities, including in the process of battery breaking, as well as at secondary lead smelters. It identifies stack and fugitive emissions as the key sources of air pollution, and provides an overview of the different technologies used to treat air emissions from secondary lead smelters, the most common of which are baghouses. Best work practices, such as cleaning plant roadways twice daily and enclosing storage areas to minimize contamination, are also discussed. To provide context for the discussion, the section also presents a summary of air emission standards for secondary lead smelters in Canada, Mexico and the United States.

Aside from ESM practices to manage air pollution, Section 5 describes options for the ESM of spent acid electrolyte and wastewater. This includes, for example, neutralizing wastewater through pH adjustment and leachate-testing the resulting filter cake. Issues surrounding the recycling of polypropylene plastics and other solid waste (i.e., other plastics and separators, and cardboard) are also discussed. The section concludes with a short description of decommissioning and closure plans, including what those plans should include to ensure that SLAB recycling facilities will not pose a future threat to human health and/or the environment.

Section 6 identifies and examines four key aspects of ESM performance at SLAB recycling facilities. These include occupational health standards; the use of personal protective equipment (PPE); control measures to minimize environmental, health, and safety risks; and monitoring systems to track environmental performance. Also discussed are the minimum requirements for emergency plans, which outline the procedures to be implemented at SLAB recycling facilities in case of emergencies such as fires, chemical spills, explosions, or unplanned releases of hazardous products.

The final section of the guidelines, Section 7, includes best practices for auditing and reporting. It is recommended that all audits at SLAB recycling facilities be conducted by a certified professional and follow the guidelines set by the International Standards Organization (ISO 19011 and ISO 17021), or an equivalent standard. For reporting purposes, it is also recommended that facilities implement and maintain a tracking system for controlling, weighing or counting, and documenting total inbound and outbound materials, wastes, and equipment and components sent for recycling.

Preface

Spent lead-acid batteries (SLABs) from automobiles, as well as from industrial, commercial and institutional applications, are one of the most recycled products in the world. In Canada, Mexico and the United States, SLAB recycling rates are close to 100 percent. When carried out properly, SLAB recycling can be an environmental success story; however, poor lead battery recycling practices, even on a small scale, can result in serious, long-lasting harm to workers, communities, and the environment.

The objective of these guidelines is to identify and consolidate best practices and technologies for recycling SLABs in a manner that protects the environment, health, and safety of workers and the public. These guidelines also provide recommendations on how to implement environmentally sound management (ESM) practices and technologies within new and existing SLAB collection, storage and recycling facilities that operate in North America.

The development of the guidelines was in direct response to the findings in the CEC Secretariat's 2013 report entitled *Hazardous Trade? An Examination of US-generated Spent Lead-acid Battery Exports and Secondary Lead Recycling in Canada, Mexico, and the United States*. One of the key findings in that study was that the regulatory frameworks covering secondary lead smelters in Canada, Mexico and the United States did not provide equal levels of environmental and health protection.* In addition to the findings, the 2013 report presented several recommendations to the CEC Council on how to ensure that SLABs are managed in a way that protects workers and the general public from the lead emitted during the recycling of SLABs in Mexico. Key among these was that the governments of all three countries work together with the North American lead smelting industry and nongovernmental organizations (NGOs) to develop strategies to support the adoption of ESM practices and technologies throughout the region.

The development of these technical guidelines presents an opportunity to widely disseminate scientifically-based information on the ESM of SLABs for North America. With that said, these guidelines do not change or substitute for statutory requirements and/or regulations which may be applicable to a particular facility or situation. It is the responsibility of each individual facility to ensure conformity with all legal requirements, which may vary by jurisdiction.

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We are also grateful to CEC staff, the editors, and the translators who made this report readable and available in three languages.

* Commission for Environmental Cooperation 2014a.

1

Background and Objectives of the Project

1. Background and Objectives of the Project

The Commission for Environmental Cooperation (CEC) of North America is an intergovernmental organization created by Canada, Mexico and the United States under the North American Agreement on Environmental Cooperation (NAAEC).[1] The CEC was established to address regional environmental concerns, help prevent potential trade and environmental conflicts, and promote effective enforcement and environmental law. The Agreement complements the environmental provisions of the North American Free Trade Agreement (NAFTA).

As part of its 2013–2014 Operational Plan, CEC's Council (its governing body) approved a project to address the environmentally sound management (ESM) of selected end-of-life vehicle batteries in North America, including spent lead-acid batteries (SLABs).

ESM is one approach to ensuring that hazardous wastes and recyclables, including those crossing international borders, are managed in a way that is protective of human health and the environment.[2] The Organization for Economic Cooperation and Development (OECD) defines ESM as "a scheme for ensuring that wastes and used and scrap materials are managed in a manner that will save natural resources, and protect human health and the environment against adverse effects that may result from such wastes and materials."[3] There are numerous recognized benefits that come from adopting and implementing ESM practices, including:

- **increased business opportunities for companies**—clients now frequently demand that processors of end-of-life components associated with their products use ESM practices, therefore ESM can be a marketing advantage for all companies throughout the supply chain;
- increased recovery of materials of high economic value, such as lead;
- enhanced operational efficiency by implementing new systems and procedures that focus on **re-using, recycling and reducing waste**;
- improved worker health and safety, as well as protection of the local community and the environment; and
- assurance of meeting regulatory and legal requirements.

With a view to fostering ESM in the recycling of SLABs, strengthening the competitiveness of this sector globally and within North America, promoting safer working environments, and fostering the creation of new jobs, in 2014 the CEC commissioned the development of technical guidelines on ESM for secondary lead smelters and other facilities that process SLABs, to enhance these facilities' capability to implement ESM practices.

The CEC has undertaken previous work to support the ESM of SLABs, which has resulted in the following documents:

- *Practices and Options for Environmentally Sound Management (ESM) of Spent Lead-acid Batteries within North America* (December 2007); and
- *Hazardous Trade? An Examination of US-generated Spent Lead-acid Battery Exports and Secondary Lead Recycling in Canada, Mexico, and the United States* (April 2013).

These technical guidelines are meant to build on, and draw from, the documents identified above and other relevant national and international guidance and documents that may exist—including, for example, guidance established under the work of the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal*.

1. Commission for Environmental Cooperation 2014b.
2. Commission for Environmental Cooperation 2007.
3. Organisation for Economic Co-operation and Development 2007.

1.1 Background

Spent lead-acid batteries (SLABs) from automobiles, as well as industrial, commercial and institutional applications, are one of the most recycled products in the world. In Canada, Mexico and the United States, SLAB recycling rates are close to 100 percent. There is a long history of SLABs having an economic value; collecting and recycling SLABs is economically sound and sustainable, which supports an active collection and return market.

When carried out properly—as evident in the best practices of several North American and European facilities—SLAB recycling can be an environmental success story. The recycling of SLABs provides a critical and stable supply of lead to the battery industry, reduces the need to mine for new lead, and diverts batteries from disposal. In addition to high recycling rates, highly sophisticated pollution control technologies and management practices make it possible for battery recycling facilities, called secondary lead smelters, to minimize lead emissions and protect worker health and safety. However, poor lead battery recycling practices, even on a small scale, can result in serious, long-lasting harm to workers, communities, and the environment.

Lead is a persistent, bioaccumulative and toxic substance, and the manner in which SLABs are managed (from collection through to recycling) is an important public health, environmental and economic issue.[4] It is now widely acknowledged in the scientific community that there is no "safe" threshold for levels of lead in the blood.[5] When absorbed by the body, lead can cause toxicity to the nervous system, heart, kidneys, bones and reproductive organs. If not managed properly, lead presents a serious risk to workers as well as to community members who live in close proximity to smelting facilities, especially young children.[6]

Increasingly stringent environmental regulations and performance requirements have led to steady improvements in the technologies and practices used in Canada and the United States. However, these changes have not occurred to the same extent in Mexico.

Given the ongoing and shared interest of the CEC parties (Canada, Mexico and the United States) to foster ESM in the recycling of SLABs, and to increase ESM based on current science, the development of these technical guidelines comes at an opportune time for governments and industry. Widespread adoption of ESM practices will improve both community and worker health, and environmental quality.

1.2 Rationale for Technical Guidelines

This project is in direct response to the findings in the CEC Secretariat's 2013 report entitled *Hazardous Trade? An Examination of US-generated Spent Lead-acid Battery Exports and Secondary Lead Recycling in Canada, Mexico, and the United States*. Among the key findings, the study found that between 2004 and 2011, net SLAB exports from the United States to Mexico increased substantially. The study also reported that the regulatory frameworks covering secondary lead smelters in Canada, Mexico and the United States did not provide equal levels of environmental and health protection.[7] At that time the United States had the most stringent overall framework, while Mexico, with significant gaps in its laws and regulations, was the farthest from US standards in terms of certain emission controls and requirements.[8] Mexico enacted new regulations for secondary lead smelters on 9 January 2015.

In addition to the findings, the 2013 report presented several recommendations to the CEC Council on how to ensure that SLABs are managed in a way that protects workers and the general public from the lead emitted during the recycling of SLABs in Mexico. Key among these was that the appropriate government entities in Canada and Mexico commit to achieving levels of environmental and health protections in the secondary lead industry that are functionally equivalent to those in the United States.[9] Another key recommendation was that the governments of all three countries work together with the North American lead smelting industry and nongovernmental organizations (NGOs) to develop strategies to support the adoption of ESM practices and technologies throughout the region.

The development of these technical guidelines presents an opportunity to widely disseminate scientifically-based information on the ESM of SLABs for North America. Harmonizing health and safety practices across SLAB collection and processing facilities to better protect human health and the environment will support achieving shared environmental goals in North America and may help avoid the development of pollution havens.

4. Commission for Environmental Cooperation 2014a.
5. Commission for Environmental Cooperation 2013c.
6. Commission for Environmental Cooperation 2013a.
7. Commission for Environmental Cooperation 2014a.
8. *Idem*
9. *Idem*

1.3 Objectives and Scope of Project

The main objective of this project is to develop technical guidelines that:

- identify and consolidate best practices and technologies for collecting and recycling SLABs in a manner that protects the environment, health and safety of workers and the public; and
- provide recommendations on how to implement best practices and technologies within new and existing SLAB collection, storage and recycling facilities that operate in North America.

The principle target audience for the guidelines includes staff (management and operational) at companies that collect, handle, transport and process SLABs. It is recognized that other organizations such as governments and environmental nongovernmental organizations (ENGOs) may also benefit from the content.

The technical guidelines do not cover the export and import of SLABs, as that has already been covered by the abovementioned, earlier CEC (*Hazardous Trade?*). In addition, hazardous waste export and import procedures have been explained in the earlier CEC *Crossing the Border* report. The guidelines also differ from the December 2007 CEC report, which provides high-level guidance and is not specifically geared toward addressing smelting and other facility operations for SLABs processing.[10] In contrast, the guidelines developed under this project identify best management practices and technologies at the operational level concerning the ESM of SLABs and the recovery of materials.

The technical guidelines are organized as follows:

- **Section 1** explains the background and context of the project, the rationale for the project, the objectives and scope of the project, and the organization of the report.
- **Section 2** outlines the components, uses and expected life of lead-acid batteries (LABs) and describes the steps involved in the recycling of SLABs.
- **Section 3** describes the pre-recycling steps (collection, transportation and storage) and the associated ESM considerations for each of these steps.
- **Section 4** describes the recycling steps (battery breaking, lead reduction and lead refining) and specific ESM considerations for each of these steps.
- **Section 5** describes controlling pollution at SLAB recycling facilities for air, wastewater and wastes.
- **Section 6** discusses environmental and health monitoring.
- **Section 7** outlines auditing and reporting.
- The **Appendix** provides a list of existing SLAB recycling facilities in Canada, Mexico and the United States, including their location and a short description of their operations.

Implementation checklists are provided at the end of each section in this report, providing readers with a concrete tool to carry out the ESM practices recommended in these guidelines.

The discussion in this document is intended solely as guidance. This document is not a law or regulation, nor does not it change or substitute for those statutory requirements and/or regulations which may be applicable to a particular situation. Thus, this document does not impose legally binding requirements on any governmental entity or member of the public.

10. Commission for Environmental Cooperation 2013c.

2 Lead-acid Battery Recycling in North America



2 Lead-acid Battery Recycling in North America

Virtually all of the lead contained in lead-acid batteries (LABs) in North America is recovered and recycled. The most recent study (2009–2013), commissioned by Battery Council International (BCI), estimates the recycling rate for SLABs in the United States to be 99 percent. The value is expected to be similar in Canada and Mexico. This high recycling rate is primarily driven by the high value of lead, which provides an economic incentive for recycling.

Recovering secondary lead from SLABs is economically superior to obtaining it from virgin ore. Processing secondary lead is reported to require about 25 percent less energy than mining primary lead.[11] This has resulted in a well-established infrastructure and the economies of scale necessary for the recycling of SLABs in North America and internationally.

In North America, supply constraints mean that the competition for SLABs among lead recyclers is fierce. There are fewer SLABs available for open purchase because, increasingly, secondary lead smelters and battery manufacturers operate under "tolling" agreements. With these agreements, smelters provide reclaimed lead to battery manufacturers in exchange for used lead-acid batteries, based on a negotiated trade value. Both specialized battery dealers and big box retailers encourage consumers to return their spent batteries for recycling when they purchase new batteries. Some retailers pay consumers or offer a discount on the purchase of a new battery when an old battery is returned.[12] Some retailers may charge consumers either a refundable deposit or a disposal fee, depending on local customs and laws. In turn, dealers are encouraged to return used batteries directly back to the manufacturer. This practice is referred to as "reverse distribution."[13]

A contributing factor to the fierce competition is also the increase in the North American recycling capacity during the last five years as new production has come online.

In Canada and the United States, the lead recycling industry is very consolidated. Canada has three secondary lead smelters and two facilities that combine primary and secondary lead smelting, while the United States has 15 domestic secondary lead smelters, run by eight companies. Most or all of the secondary smelters also have refining operations on site. In Mexico, the industry is much less consolidated, with 25 authorized secondary smelters. The Appendix provides a list of existing SLAB facilities in all three countries, including their locations and a brief description of their operations.

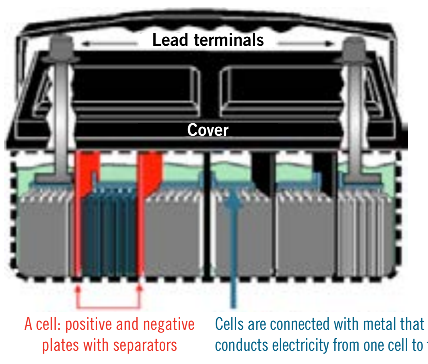
2.1 Lead-acid Battery Components, Lead Content and Typical Lifespan

As shown in Figure 1, a typical lead-acid battery (LAB) is composed of several materials[14]:

- lead in the form of metal or lead oxide (PbO) paste,
- plastic (e.g., polypropylene or co-polymer, polyvinyl chloride [PVC], polyethylene),
- sulfuric acid, and minor components such as antimony, arsenic, bismuth, cadmium, copper, calcium, silver, tin, barium sulfate, lampblack and lignin.

Figure 1

Typical Lead-acid Battery



Source: Battery Council International. 2012b. Lead acid batteries. <http://batterycouncil.org/?page=lead_acid_batteries>.

11. Waste Diversion Ontario 2009.
12. *Idem*
13. *Idem*
14. Battery Council International 2012b.

While battery manufacturers may employ different construction techniques and technologies, all LABs are made up of five basic components:[15]

- a resilient plastic container,
- positive and negative internal plates made of lead,
- plate separators made of porous synthetic material,
- electrolyte (a dilute solution of sulfuric acid and water, better known as battery acid), and
- lead terminals (the connection point between the battery and the load that it powers).

The materials are incorporated into the following constituents:[16]

- **positive and negative terminals** – made of lead (in some applications there may also be brass or copper); where the external electricity-consumer devices (e.g., cars) are connected;
- **plugs** – found on older batteries, one for each battery element; where distilled/de-ionized water can be replenished whenever needed and also to provide an escape route for gases formed in the cells (new batteries are generally sealed);
- **connectors** – made of lead;, where electrical contact is made between plates of the same polarity and also between separated elements;
- **cap and box** – made from either polypropylene or co-polymer; container of the battery element;
- **sulfuric acid solution** – the electrolyte of the battery;
- **element separators** – usually a part of the box and made of the same material; provide chemical and electrical isolation between the electrical elements;
- **plate separators** – made of PVC or other porous materials; they prevent physical contact between two contiguous plates while allowing free movement of ions in the electrolyte solution;
- **negative plates** – a metallic lead grid covered by a lead dioxide (PbO_2) paste;
- **positive plates** – metallic lead plates covered by a PbO_2 paste; and
- **battery element** – a series of negative and positive plates, placed consecutively and isolated from each other with plate separators.

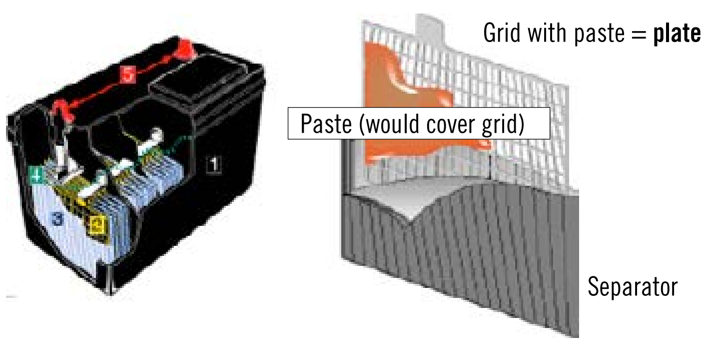
A typical plate and separator layout is presented in Figure 2.

The lead content of a LAB, which is the key economic driver for the SLAB recycling industry, depends on its intended application. Table 1 presents the average content of lead in different types of LABs.

The most recent Battery Council International (BCI) study of LAB lifespans, conducted in 2010, showed that improvements in battery design have resulted in an average lifespan of approximately 55 months, compared with an average of 41 months reported in the 2000 study. Improvements in average LAB lifespan since 1962 are presented in Table 2.

Figure 2

Lead-acid Battery Plate and Separator



Source: Battery Council International. 2012. Lead acid batteries. <http://batterycouncil.org/?page=lead_acid_batteries>.

15. *Idem*.
16. *Idem*..

Table 1. **Average Amount of Lead in Different Types of Lead-acid Batteries**

Automotive Battery Type	Average Lead Content (kg)
Passenger Car	9.9
Truck & Heavy	12.8
Motorcycle	2.2

Source: SmithBucklin Statistics Group. 2014. *BCI national recycling rate study.* <http://c.ymcdn.com/sites/batterycouncil.site-ym.com/resource/resmgr/BCI_Recycling_Rate_Study_200.pdf?hhSearchTerms=%22recycling+and+rate+and+study%22>.

Table 2. **Average Lead-acid Battery Lifespan in the US (1962 to 2010)**

Year	Average Battery Life (months)
1962	34
1995	44
2000	41
2005	50
2010	55

Source: Battery Council International. 2010. *Failure modes of batteries removed from service – A report of the BCI technical subcommittee on battery failure modes*, cited in Battery Council International and Batteries International. 2014. BCI *Yearbook & Special Pre-2014 Convention Report*. Accessed 22 May 2015. <http://issuu.com/rizzo48/docs/bci2014fullsupplement.2_copy>.

2.2 SLAB End-of-Life Management

The recycling of SLABs involves a number of steps, each of which requires the implementation of ESM practices. Although specific activities may differ from one SLAB recycling facility to another, all recyclers are likely to carry out the following steps in some fashion:

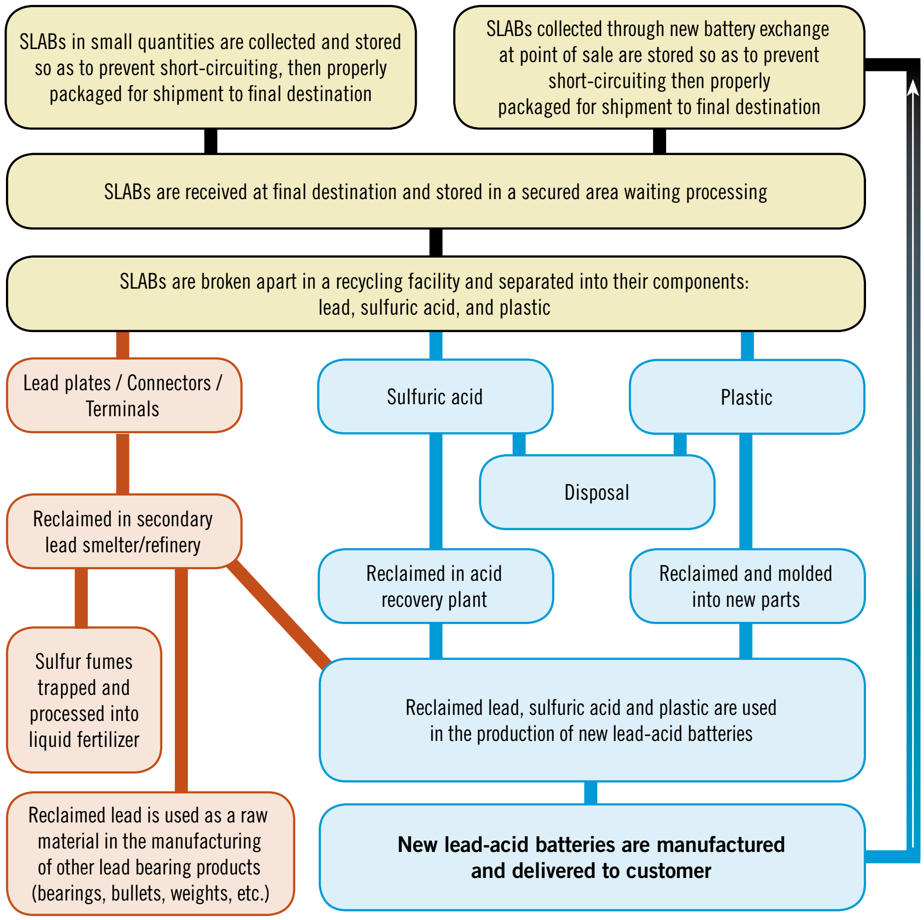
1. **Receiving:** Batteries and other recyclable raw materials are unloaded, weighed, and sent to a raw materials processing center.
2. **Separation:** Batteries are broken apart in the hammermill and separated into three main components (lead, plastic and acid) by screening and gravity separation. Each component moves into a separate processing stream.
3. **Containment:** After initial processing, recovered lead and other lead wastes are stored in a containment building designed to contain any spills with a double-lined floor and leak detection system.
4. **Purification:** The wastewater purification and treatment system neutralizes, purifies and converts the sulfuric acid into a pH-neutral liquid that is discharged in accordance with local laws and regulations. In some cases, acid can be purified and re-used, generally as electrolyte in new batteries.
5. **Smelting and refining:** After the lead is melted in blast furnaces, the reclaimed lead is mixed with other materials to produce lead alloys.
6. **Casting**: Refined lead is poured into molds and cooled. Ingot molds come in three sizes—large blocks (hogs), rectangular bars (pigs), and tub-shapes (billets).
7. **Shipping:** The refined lead and plastics are shipped to customers, to be manufactured into new batteries and other products.

Consistent with the *Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries,*[17] these steps are broken down into two categories: pre-recycling (includes collection, transportation and storage) and recycling (includes battery breaking, lead reduction and lead refining). Each of these is described in further detail in Section 3 and Section 4, respectively. Figure 3 provides a schematic representation of the SLAB recycling process.

17. Secretariat of the Basel Convention 2003.

Figure 3

Implementation Checklist for Pre-recycling of SLABs



Source: Adapted from Commission for Environmental Cooperation. 2007. *Practices and options for environmentally sound management of spent lead-acid batteries within North America.* <www3.cec.org/islandora/en/item/2323-practices-and-options-environmentally-sound-management-spent-lead-acid-batteries-en.pdf>.

3 Pre-recycling Steps: Collection, Transportation and Storage of Spent Lead-acid Batteries



3 Pre-recycling Steps: Collection, Transportation and Storage of Spent Lead-acid Batteries

As outlined in Section 2, spent lead-acid battery (SLAB) recycling involves three pre-recycling steps. Before entering the recycling facility, SLABs must be collected, transported and stored with proper care to ensure protection of the environment and human health. This section describes the technical aspects of these pre-recycling steps in detail. An implementation checklist designed to guide facility owners/operators through implementing various ESM practices throughout the pre-recycling process is provided in Table 3.

3.1 Collection, Storage, and Management of SLABs at Collection Centers

This section discusses how SLAB collection generally operates in Canada, Mexico and the United States.

The most common system used for collecting and transporting SLABs to smelters in North America is reverse distribution.[18] Reverse distribution systems involve a sales agreement between battery manufacturers and automobile service stations, retail outlets, wholesalers, and other retail locations that sell or distribute new lead-acid batteries, to collect spent batteries at the point of purchase.[19] With the exception of people who do it themselves, batteries are typically replaced at a car dealership or service station, which stockpiles the SLABs prior to pick-up by collection agents.[20] Upon delivering the new batteries, the battery manufacturer collects the spent batteries and returns them to a secondary lead smelter for end-of-life processing and extraction of refined lead, for a specified processing fee, or "toll." The refined lead is then used in the production of new batteries. This type of collection system is predominantly used in Canada and the United States, and to a lesser extent in Mexico.

Another method of SLAB collection is through brokers or aggregators. Some retailers, service stations and scrap yards may not have agreements with battery manufacturers. In these cases, they may sell SLABs to scrap dealers, who then sell them to the producers or recyclers.

In Mexico, the volume of tolling business (return of SLABs to manufacturers by battery dealers) is significantly less than that in Canada or the United States. Whereas in Canada and the United States a consumer can receive anywhere between US$10–20 for returning a used battery to a retailer, battery collectors in Mexico often charge consumers a fee for collecting used batteries, especially if the secondary smelter charges the battery collector to accept these batteries.[21] As a result, Mexico's supply chain is more fractured, with many smaller players having a more significant role in SLAB collection. Therefore, locations that sell and distribute new lead-acid batteries account for a much smaller percentage of total SLAB collection. Many batteries are collected through more-specialized channels in rural areas, or by small family businesses and brokers who purchase SLABs and then resell them to smelters. In rare cases, independent automobile service stations may sell batteries directly to nearby smelters.[22]

Part of the difference in the SLAB collection infrastructure between the three countries is explained by differences in regulations. In the United States, most states have passed laws banning the disposal of SLABs in landfills and have established deposit systems for new battery sales, mandating retailers, wholesalers and manufacturers to take back SLABs.[23] Canada and Mexico do not have specific laws pertaining to the collection of SLABs at the federal level, but do have various take-back programs in place, such as the lead-acid battery stewardship programs in British Columbia,

18. Commission for Environmental Cooperation 2013b.
19. *Idem*.
20. Commission for Environmental Cooperation 2007.
21. Commission for Environmental Cooperation 2013b.
22. *Idem*.
23. *Idem*.

Manitoba, and Prince Edward Island, and Johnson Controls' reverse distribution system in Mexico.[24]

Notwithstanding the significant differences in how the collection infrastructure works in Canada, Mexico and the United States, it generally involves several participants, including (but not limited to):

- lead-acid battery consumers,
- various retail outlets for lead-acid batteries,
- auto repair shops,
- small, local, rural, family-owned businesses that collect and consolidate small numbers of SLABs for sale to various intermediaries,
- scrap dealers,
- brokers and consolidators,
- battery manufacturers that accept used batteries when delivering new batteries to various outlets, and a range of other players.

Together these various players provide a continuous flow of SLABs to the secondary lead recycling industry. All of the players in the SLAB supply chain need to be educated on the importance of sending SLABs to properly licensed companies who recycle SLABs while using high environmental standards and who comply with applicable laws. Unregulated recycling operations and informal methods of extracting lead—often referred to as "backyard" smelting—are not ESM and are responsible for high levels of environmental lead contamination.[25]

3.1.1 Temporary Storage of SLABs at Collection Centers

SLAB storage is considered a temporary step before transportation to the recycler. Proper storage of SLABs is necessary to prevent accidental releases into the environment. The following measures are considered ESM practices that should be followed at all temporary SLAB storage facilities:

- **Inspection:** All batteries entering the facility should be inspected to ensure that they are not damaged or leaking (Section 3.1.2 discusses how to manage damaged/leaking SLABs).
- **Covered storage area:** SLABs should be stored in a location that is protected from precipitation (e.g., rainfall, dew, fog) and other water sources.
- **Away from heat source:** SLABs should be stored away from heat sources such as boilers, furnaces or exhaust outlets.
- **Well sealed, acid-resistant foundation:** Where extended storage times are involved (greater than 60–90 days), SLABs should be stored on an impermeable pad made of acid-resistant concrete or other acid-resistant foundation material, with curbing or other means of spill containment. New concrete can be made acid-resistant by sealing it with a concrete sealer and then coating it with a two-part epoxy coating. If the concrete is a pre-existing floor, the top layer should be skimmed or bead blasted off to expose fresh and unsoiled concrete. Any cracks or holes should be filled and made level, after which a sealer and epoxy coating can be applied. The collection area should have its perimeter faced with a curb to prevent leakage beyond that area.
- **Good runoff collection:** The SLAB storage site should be designed so that any drainage is collected at one collection point (a collection sump where water or other liquids will drain and be captured), to prevent unplanned releases.
- **Adequate ventilation:** If enclosed, the SLAB storage location should have an exhaust ventilation system or have frequent air flow to control emissions, exposures, and chemical hazards in the workplace. There are different types of ventilation systems available. The appropriate system to use will depend on a number of factors, such as emission sources, worker behavior, and air movement in the area. Schematics of a number of ventilation systems are presented on the OSHA website.[26]
- **Restricted access:** Ensure that the SLAB storage site is secure. Access to the SLAB storage area should be restricted through use of locked gates, perimeter fencing or doors, to ensure that unauthorized personnel cannot gain access.
- **Emergency preparedness:** SLAB storage areas should be equipped with an emergency shower for personnel and with spill cleanup material to address any spills that may occur. In addition, fire extinguishers should be available to handle small fires, should they occur.
- **Storage volumes:** Collection sites should be properly designed to store a reasonable number of SLABs collected during a typical business cycle. The appropriate size of the storage area will vary by location. It is important to note that SLABs should not be speculatively accumulated; speculative accumulation is undesirable due to the lack of proper storage facilities and the potential deterioration over time.
- **Storage time:** Collection sites should not store SLABs for long periods of time. The longer SLABs sit at a storage site, the greater the risk of damage, particularly from acid electrolyte leakage. The

24. *Idem.*
25. Commission for Environmental Cooperation 2007.
26. United States Department of Labor n.d.(a).

Figure 4

Example Warning Sign Regarding Non-lead Batteries

Source: Battery Council International. 2010. *Failure modes of batteries removed from service – A report of the BCI technical subcommittee on battery failure modes*, cited in Battery Council International and Batteries International. 2014. *BCI Yearbook & Special Pre-2014 Convention Report*. Accessed on 22 May 2015. <http://issuu.com/rizzo48/docs/bci2014fullsupplement.2_copy>. Used with permission.

appropriate length of storage time should be assessed on a site-by-site basis, but effort should be made to move SLABs to their final destination as soon as practical. Generally, storage times of longer than 60–90 days require additional facility design considerations.

- **Identify and segregate batteries by chemistry**: Secondary lead smelter operators are finding an increasing number of discarded non-lead-acid batteries, which are not used for the same purpose as SLABs, in deliveries of SLABs to their facilities. Discarded lithium-ion (Li-ion) batteries, in particular, are often not labeled as such and are difficult to identify through visual inspection. These batteries present a significant safety hazard when they are intermingled with SLABs in the lead recovery process, as they are highly reactive and can explode violently. Because of the serious danger they present to workers, discarded Li-ion batteries should never enter the SLAB recycling stream. To prevent this from happening, operators (including employees and facility owners) of smaller storage sites should inspect all batteries entering the facility and remove and label any non-lead batteries for separate handling and storage. Furthermore, collection site employees should be trained in the hazards of these batteries and the proper means to visually inspect them. While the responsibility for sorting battery chemistries is shared by all players, the initial collectors are in a uniquely important position to ensure that non-lead batteries do not enter the recycling stream, as they handle each battery individually. Nickel cadmium (NiCd) batteries are often used in smaller applications (e.g., golf carts) and can look similar to SLABs. These NiCd batteries in particular can negatively affect smelter and refining chemistry and operations, and should be identified and removed from the SLAB processing stream. Figure 4 presents a warning sign that can be used to alert employees to the dangers posed by non-lead batteries.

Examples of inexpensive approaches suitable for small storage sites, which could be applicable to Mexico, where many small local, rural and family owned businesses are involved in SLAB collection and consolidation, are presented in Figure 5 below.

In the Philippines and the United Kingdom, some facilities use wire mesh cages for temporary storage of SLABs.[27] The cages are constructed of stainless or heavy gauge steel with an open mesh floor and wheels running on nylon bearings.[28] In order to prevent unauthorized access, the cages have a lockable lid and are chained to the outside of the

Figure 5

SLAB Storage Cages Used in the Philippines (left) and the United Kingdom (right)

Source: Wilson, B. 2009. Recycling used lead-acid batteries: A model life cycle approach. Presented at the 13th Asian Battery Conference – International Secondary Lead Conference. <www.ilmc.org/Presentations/ABC/Recycling%20Used%20Lead%20Acid%20Batteries%3B%20A%20Model%20Life%20Cycle%20Approach.pdf>.

27. Wilson 2009.
28. *Idem*.

store or service station. The use of cages, as opposed to a closed container, prevents the risk of buildup of explosive gases and keeps SLABs off the ground, allowing for easy identification of any spillage and the appropriate action to be taken to contain and clean up any spills.[29] Aside from storage purposes, the cages can also be used to transport SLABs to collection centers, provided they are secured to the inside of the vehicles used for transportation.[30] Use of the cages reduces the need to handle SLABs individually, which significantly reduces the risks of accidents and personal injury. When used, cages should be covered to avoid any contact between rainfall and SLABs.

3.1.2 Management of Leaking SLABs at Collection Centers

SLABs that are damaged (e.g., cracked cases) or have missing caps have the potential to leak battery acid. Because improper handling of this acid can lead to severe personal injury to eyes and skin, appropriate personal protective equipment (PPE) should be worn when handling a battery that may be damaged or leaking.

Damaged SLABs that are not visibly leaking may be packaged separately in heavyweight polyethylene plastic bags (minimum 6 mil thick), closed securely with an adjustable plastic tie and placed in the middle of the top layer of stacked batteries.[31]

It is important that any acid drained from damaged batteries be cleaned up, using appropriate procedures and equipment (described in the next section) and in accordance with all local, state/provincial and federal laws.

3.2 Packaging and General Guidelines for the Transportation of SLABs

3.2.1 Preparing SLABs for Transportation: Proper Packaging

Ensuring that SLABs are properly packaged before shipping them to the recycling facility is critical to protecting worker health and safety and the environment. Improperly stacked and stored batteries, as illustrated in Figure 6, are not only a safety hazard, but can result in negative effects on human health and the environment if they crack and leak.

While it is not possible to eliminate all risk, the following precautions should be taken to minimize the risks associated with the transportation of SLABs:[32]

29. *Idem.*
30. *Idem.*
31. Battery Council International 2010c.
32. *Idem.*
33. Battery Council International 2010c.

- **Prior to packaging, complete an inspection of the batteries for damage.** (Section 3.1.2 discusses management of leaking and damaged SLABs.) This should be done while wearing the appropriate personal protective equipment (PPE) (discussed in greater detail in Section 6.3.1).
- **Seal all battery openings or make sure all vent caps are in place**. If caps are missing, they should be replaced; if replacement is not possible, vent holes should be sealed with foam. Acid leaks through vent holes can also be prevented by stacking batteries in an upright position no more than three batteries high to minimize the risk of the stack becoming unstable.[33]
- **Damaged batteries that are not visibly leaking electrolyte must be put in heavyweight polyethylene plastic bags** (minimum 6 mil), properly sealed with plastic tie and placed in the middle of the top layer.
- **Lead wheel weights must be put in a plastic bucket and covered**. The bucket should be placed in the center of the top layer, with the handle secured to avoid contact with battery terminals.
- **If possible, stack returned SLABs using pallet provided with new shipment**. Pallets used for SLAB transportation should meet the following minimum requirements:
  - Maximum pallet size: 48" x 44" (122 cm x 112 cm) or 48" x 40" (122 cm x 102 cm).
  - The pallet must be sturdy and durable enough to handle the weight of the battery load.
  - The pallet should have no broken or missing boards and no nails, debris, or splinters sticking up, which could puncture the SLABs.
  - Pallet boards should preferably be a minimum of 5/8" (12.7 cm) thick.
  - The pallet should be constructed with a minimum of three bottom runners (see Figure 7).
- **Place a layer of cardboard on the pallet** to prevent the batteries from sliding off and to absorb small amounts of electrolyte that might spill, then place the first layer of batteries on top. This first layer of batteries should be as level and as close together as possible. If some of the batteries are shorter, they should be placed in the center of layers. Any taller batteries should be placed on the top layer. (Note: Do not double stack cells or batteries between cardboard layers).
- **Place waffleboard (preferred) or sufficient cardboard (multiple sheets if necessary) between all layers**, including the top layer of batteries, to prevent the possibility of puncturing the batteries above and of causing short circuits (see Figure 8). Place cardboard on top of pallet.

- **Keep batteries (except for non-spillable stationary cells) upright at all times** (see Figure 9). Do not drop batteries or tip them on their sides or upside down. Put batteries carefully down on pallets in the designated battery storage area.
- **To prevent shorting, protect terminals with non-conductive caps, tape, or other insulating material.**
- **Batteries with terminals on the side must be stacked so the posts are facing away from each other** (see Figure 10). Terminals on the side must never touch, to prevent short-circuiting.
- **Terminals on the top must be positioned toward the outside of the pallet** so the layer above it leans toward the center. Make sure that no batteries are overhanging the waffleboard or sheets of cardboard (see Figure 11).
- **Stud terminal batteries should be on the top layer** (see Figure 12). If this is not possible, extra layers of cardboard should be placed between the layers of batteries to prevent punctures. This is also important when stacking three layers high.
- **Place cardboard on top of the final SLAB layer** so that the containerized units can be stored on top of each other.
- **Confirm that the total height of the package does not exceed 1.5 times the battery load width**.
- **The completed pallet should be stretch-wrapped in plastic as tightly as possible** to prevent movement in any direction (horizontal or vertical) during the loading, transportation and unloading process (see Figure 13). Stretch wrap works best if it is pulled tight before stretching it around the corners of the SLAB load on the pallet. Start with the stretch wrap turned sideways to create a rope effect. Still using the rope effect, wrap the top layer twice (or as many times as necessary to stabilize the load) again, crossing over the top each time to form an X-pattern. This will pull the batteries towards the center to prevent batteries from falling off of the pallet, which is a DOT requirement. Hold the stretch wrap open, wrap around the bottom layer at least twice, being sure to catch the edges of the pallet. Finally, after placing cardboard on top of the top layer of batteries, wrap the stretch wrap around the top layer at least twice, then tear at the last corner. A video showing and describing best practices for packaging SLABs for transport is available on Battery Council International (BCI)'s website.[34]
- **Once stretch-wrapped, one or more plastic bands should be placed around the batteries** to provide for a more secure load. This is an optional step that is encouraged depending upon what method of transportation is used and the duration of further transportation.

3.2.2 General Transportation Guidelines

Once SLABs have been securely packaged and stacked on pallets, the following ESM practices should be followed to ensure safe transportation to a recycler:

- **Pallets of SLABs should be securely in place:** To ensure that battery pallets do not shift during transportation, the transporter should apply the appropriate "blocking and bracing" methods to secure the load from horizontal and vertical movement. The term "blocking and bracing" refers to various methods prescribed in the Transportation of Dangerous Goods (TDG) Act and other transportation legislation to ensure that products are securely tied down with bracing and are held in place in a transportation vehicle by blocking, so that they are stable and do not move around or fall over.
- **Appropriate shipping documentation, labels and markings should be provided with every vehicle transporting SLABs:** In Canada and Mexico, SLABs are considered dangerous goods, for the purposes of shipping, and therefore vehicles used to transport SLABs are required to display the appropriate labels and/or markings to properly communicate that dangerous goods are onboard.[35,36] Documentation used for transportation (e.g., manifests, bills of lading) should also properly communicate information on the material being transported, including quantity and weights. In the United States, vehicles transporting SLABs in accordance with 49 C.F.R. Part 173 are exempt from US Department of Transport (DOT) requirements. In other words, if a shipper follows specific practices, such as properly palletizing and loading SLABs, and does not ship any other hazardous materials at the same time, many of the requirements of hazardous waste transportation regulations can be avoided.[37] Further information on requirements specific to each country is provided in separate textboxes at the end of this section.
- **The transport vehicle should be outfitted with spill cleanup equipment and any other equipment necessary to ensure health and safety**: All vehicles transporting SLABs should have a spill kit on board and any other equipment necessary to deal with a spill and related worker injuries. At a minimum, spill kits should include the following:
  - chemical-resistant poly-drum(s), with lids and rings—57 liter (15 gallon), 113 liter (30 gallon) and/or 208 liter (55 gallon);

34. Battery Council International 2012a.
35. Transport Canada 2010.
36. Mexico Secretariat of Communications and Transportation. n.d.
37. Battery Council International 2012a.

Figure 6

Improper Placement of SLABs on Pallet

Source: Krum, Gretchen. Improper Storage 2. E-mail communication with the author, 22 July 2014.

Figure 7

Wooden Pallet Used to Transport SLABs

Source: Palletxpert. n.d. Two entry wooden pallet. Accessed on 24 April 2015. <www.palletxpert.com/two-entry-wooden-pallet/>.

Figure 8

Proper Layering of Cardboard between and on Top of SLAB Layers on Pallet

Source: Battery Council International. 2010. Used with permission.

Figure 9

SLABs Stored in Upright Position

Source: Krum, Gretchen. Battery stacking. E-mail communication with the author, 22 July 2014.

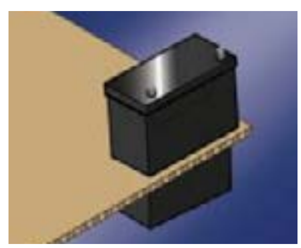
Figure 10

Incorrect (left) and Correct (right) Positioning of Batteries with Side Terminals

Source: Battery Council International. 2010. Used with permission.

Figure 11

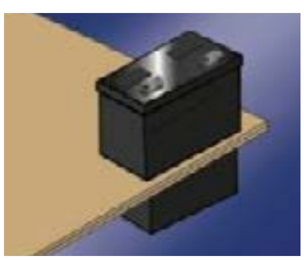
Correct Positioning of Batteries with Terminals on Top



Source: Battery Council International. 2010. Used with permission.

Figure 12

Stud Terminal Batteries Placed on Top Layer



Source: Battery Council International. 2010. Used with permission.

Figure 13

Pallets of SLABs Securely Strapped and Ready for Transport

Source: Battery Council International. 2010. Used with permission.

- soda ash—used to neutralize any spilled acid;
- vermiculite—used to absorb the neutralized effluent/liquid spilled;
- chemical-resistant gloves;
- eye protection; and
- required labels for spilled material.

- **Drivers and auxiliary staff should be properly trained:** All transport personnel should be aware of the hazardous nature of SLABs and should be trained in emergency procedures in case of fire, spills or other accidents, and in how to contact emergency services.

- **Personal protective equipment (PPE):** PPE should be provided for all staff transporting SLABs and should be accessible during transportation. This includes chemical-resistant gloves and eye protection (safety glasses and/or face shield). It is also recommended that the driver wear shoes with chemical-resistant sole and steel toes. A driver may need PPE if the batteries shifted during transportation and were dislodged from their packaging. The result would be damage to the battery cases, potentially causing electrolyte to leak onto the trailer floor, which the driver would need to address before driving any further.

Battery Transportation Regulations in Canada

Any export, import or transit shipment of SLABs to or from Canada, or in interprovincial movement within Canada, is considered to be a shipment of hazardous waste or hazardous recyclable material and must be carried out in accordance with Canada's Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations (EIHWHRMR).[38] A series of tools has been developed by Environment Canada to assist with navigating the EIHWHRMR, including a user and classification guide.[39] These tools and others are available at <www.ec.gc.ca/gdd-mw/default.asp?lang=En&n=8BBB8B31-1>.

The transport of SLABs is also subject to controls as mandated by Canada's commitment as a signatory to a number of international agreements, including: the United Nations Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal; the OECD (Organization for Cooperation and Economic Development) Decision of Council on the Control of Transfrontier Movements of Wastes Destined for Recovery Operations; and the Canada-US Agreement on the Transboundary Movement of Hazardous Waste.[40] Controls include pre-notification process, prior inform consent from importing country, and permit and manifest documents.

SLABs are also regulated under the federal Transportation of Dangerous Goods Act and Regulations, which provide the detailed requirements for the transportation of dangerous goods (TDG) on federal lands and roads. One of those requirements is that carriers must placard vehicles and freight used to transport SLABs anywhere in Canada.[41] If a company wishes to carry out an activity related to transporting dangerous goods in a way that is not in compliance with the TDG Regulations, it must apply for an Equivalency Certificate and must be able to show that the way in which the activity will be carried out will provide a level of safety equivalent to those specified in the Regulations.[42] Examples of these certificates are available on Transport Canada's website, at <wwwapps.tc.gc.ca/saf-sec-sur/3/tdgcert-tmdcert/certificatesmenu.aspx>.

Shipments within Ontario are exempt from manifesting if they are going to a smelter to be "wholly consumed."

38. Canada, Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations (SOR/2005-149).
39. Environment Canada 2014b.
40. Environment Canada 2014a.
41. Transport Canada 2010.
42. *Idem.*

Battery Transportation Regulations in Mexico

In Mexico, lead-acid batteries are considered hazardous waste under the General Law for the Prevention and Management of Waste (*Ley General para la Prevención y Gestión Integral de los Residuos*—LGPGIR). This law stipulates that federal authorization is required for transport, including the import and export, of hazardous waste in Mexico, and that SLABs may only be imported into Mexico for recycling and recovery, and not for final disposal in landfills.[43]

The transport of hazardous wastes in Mexico is also regulated by the Regulation for the Land Transport of Hazardous Materials and Wastes, published by the Mexican Secretariat of Communications and Transport.[44] In addition to requiring transporters to adhere to a set of packaging and placarding requirements, this Regulation sets out a list of documentation requirements that transporters of SLABs must follow. For example, Article 50 stipulates that for the transportation of hazardous materials or wastes, the transporter must have the corresponding authorizations issued by the Secretariat and other agencies of the Federal Government.[45]

The above laws and regulations are complemented by several Official Mexican Standards (*Normas Oficiales Mexicanas*—NOMs). LABs and SLABs are specifically listed in NOM-002-SCT/2011 (List of Hazardous Materials Most Commonly Carried in Transport). Other standards related to the transportation of hazardous materials, including SLABs, include:[46]

- ✓ NOM-003-SCT/2008 – Labeling Requirements for Hazardous Materials Packaging Used for the Land Transportation of Hazardous Materials and Wastes;
- ✓ NOM-004-SCT/2008 – Placarding Requirements for Transport Units Engaged in the Land Transportation of Hazardous Materials and Wastes; and
- ✓ NOM-010-SCT2/2009 – Compatibility and Segregation Requirements for the Storage and Transportation of Hazardous Materials and Wastes.

Battery Transportation Regulations in the United States

Facilities shipping lead-acid batteries by ground in the United States are required to comply with certain provisions of the federal Hazardous Material Regulations. Provision 49 CFR 173.159 stipulates that batteries must be prepared and packaged for transport in such a way as to prevent a dangerous evolution of heat, short-circuits, and damage to battery terminals.[47] This means, for example, firmly securing SLABs to a pallet and packaging them in a way that prevents the terminals of adjacent batteries from making contact with each other or with other metal.

SLABs are not subject to any other Department of Transportation (DOT) requirements if packaged in accordance with 49 CFR 173.159, shipped by road or rail, and if all of the conditions below are met:[48]

- ✓ There are no other hazardous materials in the same vehicle.
- ✓ The SLABs are loaded or braced in such a way as to prevent damage and short-circuits.
- ✓ Any other material loaded in the vehicle is secured so as to prevent contact with or damage to the batteries.
- ✓ The vehicle carries only material provided by the battery shipper.

43. Semarnat. General Law for the Prevention and Management of Waste (*Ley General para la Prevención y Gestión Integral de los Residuos*). Article 5, Sections XXXII and XXIX, and Article 31, Section IV.
44. Secretariat of Communications and Transport (*Secretaría de Comunicaciones y Transportes*) (Mexico). Regulation for the Land Transport of Hazardous Materials and Wastes.
45. *Idem*.
46. Hunt 2015.
47. United States Congress, Hazardous Materials Regulations (Title 49 CFR Part 173).
48. *Idem*.

3.3 Storage of SLABs at the Recycling Facility

Due to the large numbers entering recycling facilities, storage of SLABs prior to recycling is often necessary. While the guidelines presented here are very similar to those described for storage at collection centers (Section 3.1), the quantity of SLABs stored at recycling facilities is much larger and therefore additional measures must be taken to ensure proper storage. These measures are described below.

3.3.1 Identify and Segregate Battery Chemistries

As noted in Section 3.1, an increasing number of other battery chemistries, particularly lithium-ion (Li-ion), are entering the recycling stream and making their way into secondary lead smelter operations. Tackling non-lead batteries is an important safety issue for secondary lead smelters, as mixing battery chemistries is a serious and potentially very dangerous safety hazard. When commingled with SLABs in the lead recovery process, Li-ion batteries are highly reactive and can violently explode. At the same time, nickel-cadmium (NiCd) batteries cause quality control problems during smelting and refining.

Although non-lead batteries should ideally be identified and segregated from SLABs at the initial point of collection, a second inspection should also be done at the storage facility to ensure that non-lead batteries do not enter the smelter. Often, discarded Li-ion batteries are not labeled as such, which makes it difficult to identify them through visual inspection. It is therefore critical that secondary smelter employees know the proper means to conduct visual inspections of batteries, and that they understand the hazards and quality control problems presented by non-lead batteries.

While efforts are currently underway by the battery industry to address this issue, no solution is available at time of writing.

3.3.2 Outdoor SLAB Storage Areas

Outdoor storage areas should be covered to prevent rainwater collection and reduce contaminated run-off. Moreover, SLABs should be kept on an impermeable surface such as a concrete slab or asphalt that has secondary containment (a second level of protection in case the first level of containment fails). Figure 14 illustrates improper outdoor storage of SLABs.

3.3.3 SLAB Storage Building Requirements

At most recycling facilities, storage of SLABs in shipping containers is not practical since more space is required for separately identified and labeled SLABs.

Figure 14

Improper Outdoor Storage of SLABs

Source: Krum, Gretchen. Battery stacking. E-mail communication with the author, 22 July 2014.

In some cases, SLABs are stored outside (discussed above), whereas other facilities store SLABs indoors. Buildings in which SLABs are stored should have the following design features:

- cover from the elements;
- impermeable and acid-resistant floor, with curbing (stone or concrete edging) or some means of containment for spills;
- a drainage collection system that directs spills to the effluent treatment system or an acid storage tank;
- one entrance and one exit, both of which having doors that are designed to remain closed when not in use;
- air-handling equipment (described in Section 5 of this document) that provides sufficient air changes per hour;
- an air-cleaning system that filters the air to remove lead and other particles from dust—only necessary if the storage area is not separated from the processing area;
- appropriate fire-fighting equipment; and
- security controls such as keys or passcodes so that only authorized personnel have access to the building.

Table 3. **Implementation Checklist for Pre-recycling of SLABs**

Implementation Area	Key ESM Activity	Actions and Considerations	For details, see…
Collection & Storage of SLABs prior to transportation to recycler	Inspect incoming batteries	☐ Ensure no leakage, by careful inspection of batteries upon receipt ☐ Identify and segregate non-lead materials that pose a danger at a secondary lead smelter	§3.1.2
	Storage area features	Ensure storage area: ☐ is covered ☐ is away from heat sources ☐ is on acid-resistant, well-sealed foundation ☐ has runoff collection ☐ has adequate ventilation ☐ has restricted access ☐ has emergency preparedness	§3.1.1
	Storage functions	☐ Know maximum number of SLABs that can be stored and enforce this ☐ Limit storage time to 60–90 days where practical (optional) ☐ Segregate batteries by chemistry type	§3.1.1

Transportation	Packaging of SLABs prior to shipping	☐ Inspect for damage and leaks prior to packing
		☐ Seal openings and put vent caps on
		☐ If damaged, put SLAB in heavyweight polyethylene bag (minimum 6 mil thick)
		☐ Follow pallet sizing and loading guidelines:
		  ☐ correct material between layers and on top
		  ☐ batteries upright
		  ☐ safest terminal positioning on pallet
		  ☐ height not more than 1.5 times load width
		  ☐ stretch-wrap entire pallet
		  ☐ secure load with heavy-duty plastic bands (optional)
			§3.2.1 Figures 7 -14

	Transportation to recycler	☐ Block and brace containers inside vehicle ☐ Follow regulatory requirements for all originating, transit and destination jurisdictions, for documentation, labels and markings ☐ Ensure transport vehicle has appropriate spill and related emergency equipment ☐ Ensure drivers and related staff have proper training in loading and emergency response ☐ Have correct PPE for transport drivers and staff ☐ Choose route to minimize impact of a potential spill	§3.2.2
Storage at recycler	Storage requirements	☐ Identify and segregate by battery chemistry	§3.3.1
		☐ Separate specialty SLABs that may cause operational problems if not segregated	§3.3.2
		☐ Ensure outdoor storage areas are covered and on an impermeable surface	§3.3.3 Fig. 15
		☐ Meet storage building requirements	§3.3.4

4 Spent Lead-acid Battery Recycling Steps: Battery Breaking and Secondary Lead Smelting (Lead Reduction)

4 Spent Lead-acid Battery Recycling Steps: Battery Breaking and Secondary Lead Smelting (Lead Reduction)

After the batteries have been received and stored at the recycling facility, the SLAB recycling process can begin. Many of the materials recovered from SLABs are used in the manufacture of new lead-acid batteries (LABs).[49] For example, recovered lead is often used in the lead component of new LABs, while the plastic that is recovered can be used in the manufacture of new battery cases.[50] Alternatively, plastics that cannot effectively be separated from lead components in SLABs are sometimes used as a fuel reducer supplement in lead reduction and refining operations.[51]

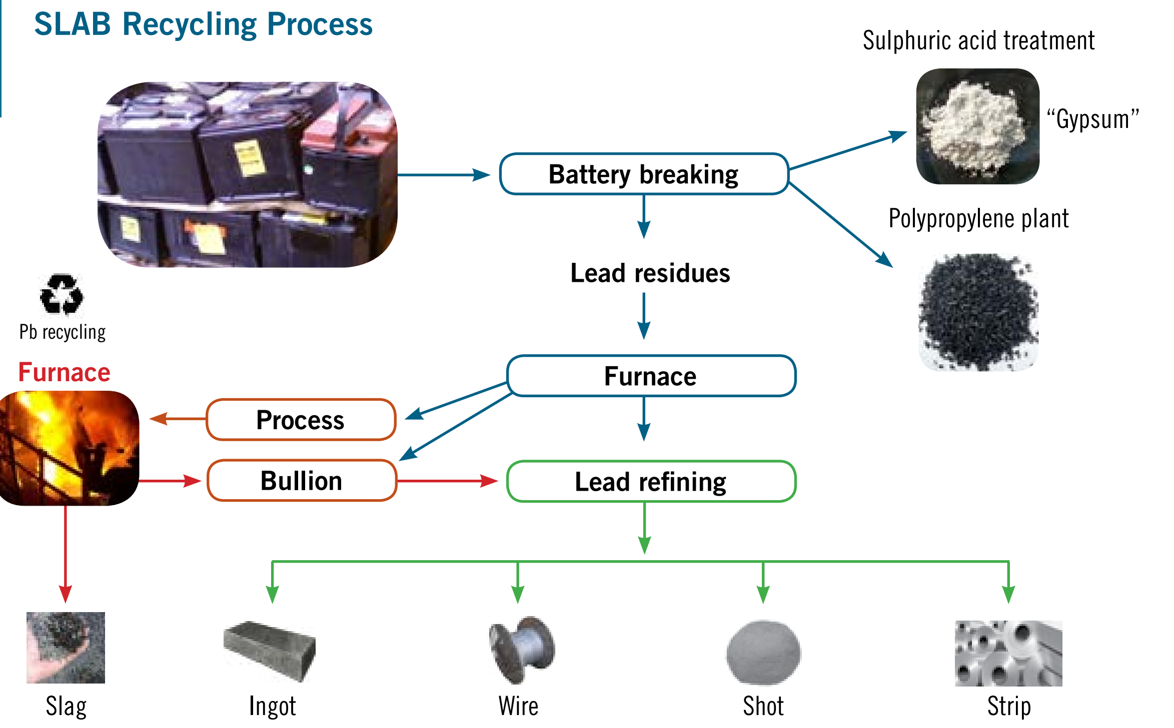
This section describes the recycling process and discusses ESM considerations that should be taken into account at each step of the battery breaking, lead smelting and lead refining process. Many of the ESM considerations are similar for both lead smelting and lead refining, therefore common ESM considerations for both processes are presented together in Section 5 of this guideline. An implementation checklist designed to help facility owners/operators monitor the implementation status of various ESM practices throughout the SLAB recycling process is provided in Table 4.

Table 4. **Implementation Checklist for SLAB Recycling**

Implementation Area	Key ESM Activity	Actions and Considerations	For details, see…
Battery Breaking	Drainage of specialized SLABs	☐ Drain specialized large format SLABs before crushing	§4.2.2
	Spills of spent acid electrolyte	☐ Train personnel to deal with spills ☐ Use correct PPE	§4.2.3
	SLAB breaking machinery	☐ Control for lead particles and sulfuric acid vapors that may be released in mechanical crushing process ☐ Control for sulfuric acid vapors that may be released in mechanical crushing with vent hoods connected to a wet scrubber ☐ Liquid discharge from wet scrubber may be acidic (if pH not controlled)—manage correctly ☐ Wash plastic chips from breaking with appropriate approach	§4.2.3
	If breaking facility and smelter are not collocated	☐ If process water from breaking facility is not at smelter, use extensive care to avoid leaks and spills when transporting the muddy water; spills can lead to lead dust contamination	§4.2.3

49. Blacksmith Institute 2012.
50. *Idem.*
51. Commission for Environmental Cooperation 2007.

Figure 15



Source: Adapted from Eco-Bat Technologies Ltd. The ECOBAT recycling cycle. Accessed 23 April 2015. <http://ecobatgroup.com/ecobat/rp/>.

4.1 SLAB Recycling Process

Spent lead-acid battery (SLAB) recycling involves three main steps, including:[52]

- battery breaking,
- lead reduction, and
- lead refining.

In some cases, all stages of the SLAB recycling process (shown in Figure 15) take place at the same facility. While less common, in other cases it is also possible that the SLAB battery breaking process occurs at one facility (described in Section 4.2), while the lead is transported to a separate facility for recycling.

4.2 Battery Breaking: Process Description and Associated Environmental and Safety Hazards

The first step in the SLAB recycling process is referred to as "battery breaking." The battery breaking process separates all components, such as lead paste, metallic plates and connectors, polypropylene and other plastics, and acid electrolyte into streams that are handled separately in the subsequent recycling steps. While there are exceptions under certain circumstances (see Section 4.2.2), all SLAB breaking should be carried out in specialized battery-breaking machines.

4.2.1 Mechanical SLAB Battery Breaking

A typical mechanical SLAB breaking process involves several steps (see Figure 16), each of which are described in detail below. ESM considerations for these breaking activities can be found in Section 4.2.3.

Battery Crushing

The dismantling process begins once the SLABs arrive at the breaking machine.[53] At this stage, SLABs are crushed into small pieces by hammer mills or other crushing mechanisms. Depending upon the location and circumstances, this breakage process may occur at a separate facility from where the lead is recovered, such as in a smelter or refinery, or in a facility adjacent to a lead smelter (which is the most common practice).[54] In other cases, recycling facilities receive broken SLABs that are already pre-processed from a local company.

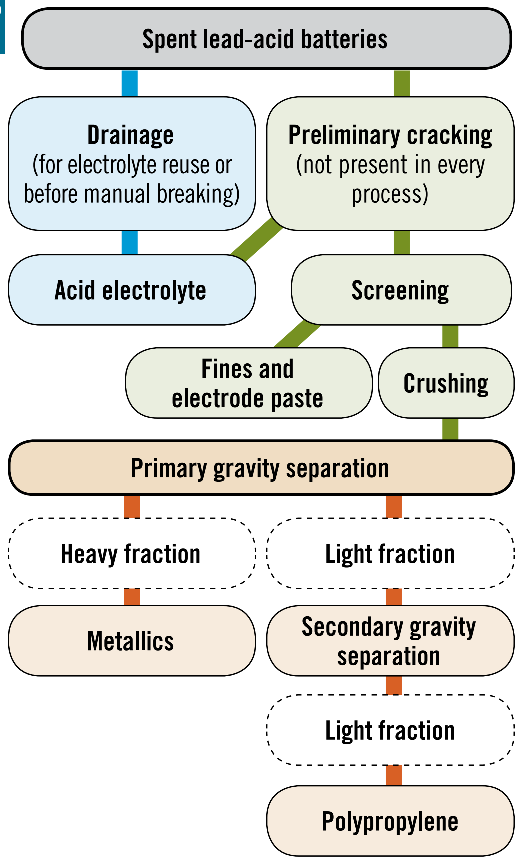
Screening

After SLABs have been crushed, a screening process takes place to split up the various lead and plastic materials into

52. Secretariat of the Basel Convention 2003.
53. Secretariat of the Basel Convention 2003.
54. Commission for Environmental Cooperation 2007.

Figure 16

Battery Breaking Process Schematic



Source: Adapted from Secretariat of the Basel Convention. 2003. *Technical guidelines for the environmentally sound management of waste lead-acid batteries*. <www.basel.int/Portals/4/Basel%20Convention/docs/pub/techguid/tech-wasteacid.pdf>.

separate streams. One level of screening separates fines (small particles and debris left over from the crushing process) from the electrode paste (lead). An additional step involves gravity separation for further separation of the crushed SLAB material into separate material streams.

Gravity Separation of Heavy Metallic (lead) and Light (plastic) Materials

Following battery breaking and the initial screening, the lead oxides and sulfates are separated from the other materials by a gravity separation process, which occurs in water through a series of sink and float tanks that separate materials based on their relative density.[55] Heavy materials such as lead paste sink to the bottom while light materials such as plastic float to the top. Heavy materials are constantly removed by a drag chain and light plastics are removed on a screen or screw. The liquid contains sulfuric acid from the spent acid electrolyte.

There are a number of different processes to further separate batteries, all using the same general principle of gravity-driven separation of materials. In the first step of the gravity separation process, the heavy fraction goes to the metallic stream. In a second gravity separation process, the light fraction (polypropylene plastic used in the battery casings) is separated from the heavier fraction. A third gravity separation divides the plastic fraction into polypropylene chips from the outside SLAB casing and the thin plastic separator material used between battery plates within the battery.

Acid Electrolyte Neutralization and Recycling

The acidic spent electrolyte is generally neutralized (pH adjusted), often with magnesium hydroxide ($Mg(OH)_2$), to precipitate out contaminants in the form of a filter cake. The pH adjustment reaction is exothermic (produces heat) and therefore the best practice is for this process to occur in fiberglass tanks, rather than polyethylene tanks. This neutralization process produces a sulfate filter cake, which, depending on the results of leachate testing carried out at a certified laboratory, is either landfilled as a non-hazardous waste or is sent for further treatment as a hazardous waste. The neutralized liquid is discharged to local sanitary lines that lead to a local wastewater treatment facility or to open waterways.

At some facilities, the acidic electrolyte is re-used. Impurities are removed from the spent electrolyte, and concentrated sulfuric acid is added to bring it up to a strength suitable for use as electrolyte in new batteries.

4.2.2 Manual Battery Breaking for Specialized SLABs Only

Although generally not considered an acceptable practice, in some very specific circumstances SLAB breaking is done manually. This is necessary for some large-format industrial batteries that are too large or heavy to put into the mechanical battery-breaking machine (e.g., older industrial SLABs from electrical utilities, large-format batteries in glass or steel casings) and whose glass or steel cases cannot be processed in the crushers.

In cases where manual battery breaking is carried out, the following measures should be followed:[56]

- where possible, puncture the large, industrial SLAB and drain the spent acid electrolyte (this is not possible for some large-format batteries);
- neutralize the spent acid electrolyte prior to discharge, or send the electrolyte to wastewater treatment or electrolyte treatment/recycling facilities (see Section 5.4);

55. *Idem*.
56. Secretariat of the Basel Convention. 2003. Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries. <www.basel.int/Portals/4/Basel%20Convention/docs/pub/techguid/tech-wasteacid.pdf>

- remove the top of the large SLAB, including plates and separators, using a circular saw or other appropriate equipment, ensuring that appropriate personal protective clothing and equipment (see Section 6) is used;
- send the plates and grids with the top of the SLAB to a lead smelter;
- send the SLAB case (plastic, glass, and steel) to recycling facilities; and
- dispose of the remaining materials properly as wastes.[57]

4.2.3 Lead-acid Battery Breaking: Environmental and Safety Hazards

If not carried out properly, battery breaking can present serious and significant environmental and safety hazards (described below). ESM practices that should be considered to minimize the risks associated with these breaking activities can be found in Section 6.

Spent Acid Electrolyte Spills

Spent acid electrolyte is a strong corrosive solution that contains lead and lead particulates. If spilled from SLABs, it can contaminate soil as well as potentially injure workers. For this reason, spent acid electrolyte should be handled by properly trained personnel equipped with personal protective equipment (PPE).

Lead-acid Battery Breaking Machinery

Mechanical lead-acid battery breaking is a potential source of lead particulates through crushing or hammer mills. Sulfuric acid vapors will also be emitted and should be controlled. Mechanical methods to control sulfuric acid vapors include a vent hood over the point of generation, which should be connected to a wet scrubber. The resulting liquid discharge from the wet scrubber is acidic (unless pH is controlled) and could be used as recycled water in the process or sent to wastewater treatment (described in Section 5) and discharged. Any leaks or spills from this system will produce a corrosive liquid containing lead.

Contaminated Plastic Chips

Plastic chips (polypropylene plastics) from the lead-acid battery breaking operation can be contaminated as much as five percent by lead. For this reason, plastic chips should be put through a second wash in an alkaline solution, followed by a second rinse cycle.[58] While this approach may be followed by some companies, other equally appropriate approaches are used which do not require these steps. For example, spin washers and other mechanical means are able to achieve the same result without significant water consumption.

Lead Dust Contamination

Because the main processes of separation are based on water techniques, the separated and fine materials from the battery breaking process are usually wet.[59] If these materials are not incorporated into a fully automated process, they will have to be shipped from the battery breaking facility to the smelter. During transport, there is potential for some of this muddy and/or watery material to spill from the truck, especially if the breaking facility and smelter are not collocated. When this wet material dries, the resulting dust may contain lead particles that, if not treated properly, can contaminate the facility as well as the surrounding community. One of the many benefits of collocating lead-acid battery breaking and smelting operations is the virtual elimination of fugitive emissions associated with transportation, as all activities occur at one site. Methods to control fine lead dusts are discussed in Section 5.3.

4.3 Secondary Lead Smelting

Secondary lead smelting includes three major operations: pretreatment, smelting and refining. These steps are presented schematically in Figures 17, 18, and 19.

Together, all of these operations in the secondary lead smelting process are referred to as lead reduction. Secondary lead smelters convert lead derived from the battery breaking process into lead that is eventually sent to refiners. The SLAB scrap obtained from the battery breaking process is a mixture of several substances:[60]

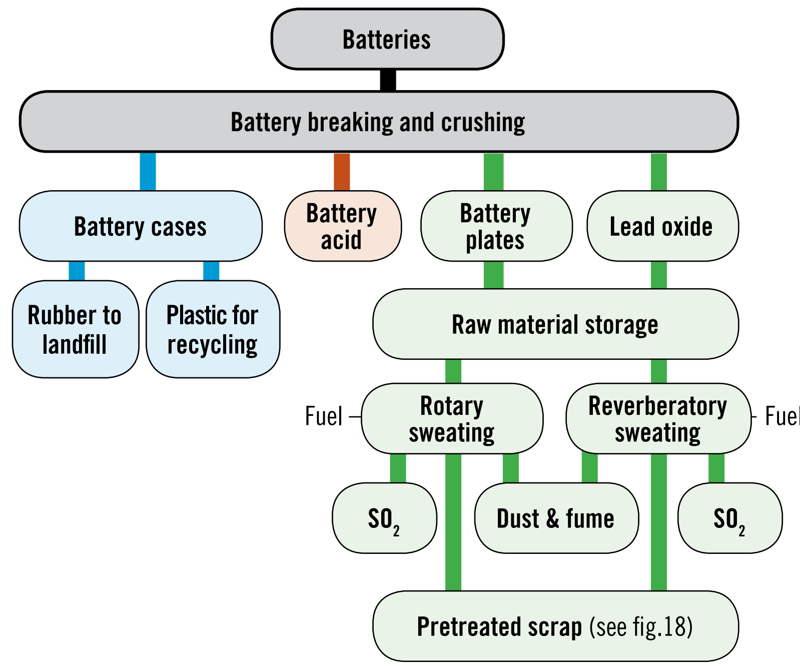
- metallic lead,
- lead oxide (PbO),
- lead sulfate ($PbSO_4$), and
- other metals such as calcium (Ca), copper (Cu), antimony (Sb), arsenic (As), tin (Sn) and sometimes silver (Ag).

Secondary (recycled) lead is usually produced using pyrometallurgical methods. Pyrometallurgical lead refining occurs in a furnace where various sources of secondary lead are combined with sufficient fluxing agents and reducing agents to produce a lead bullion that is of requisite quality and purity for various lead markets. The following inputs are introduced to the secondary lead furnace:[61]

57. *Idem.*
58. *Idem.*
59. *Idem.*
60. *Idem.*
61. *Idem.*

Figure 17

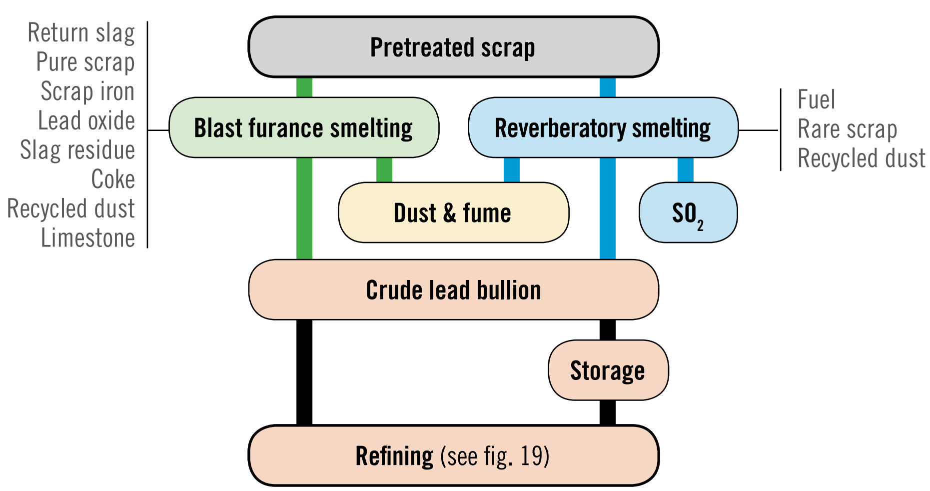
Process Flow for Typical Secondary Lead Smelting: Pretreatment



Source: Adapted from US Environmental Protection Agency. 1995. *Compilation of air pollutant emission factors. Volume 1: Stationary point and area sources.* Fifth Ed. Chapter 12: Metallurgical Industry. <www.epa.gov/ttn/chief/ap42/ch12/final/c12s11_2010.pdf>.

Figure 18

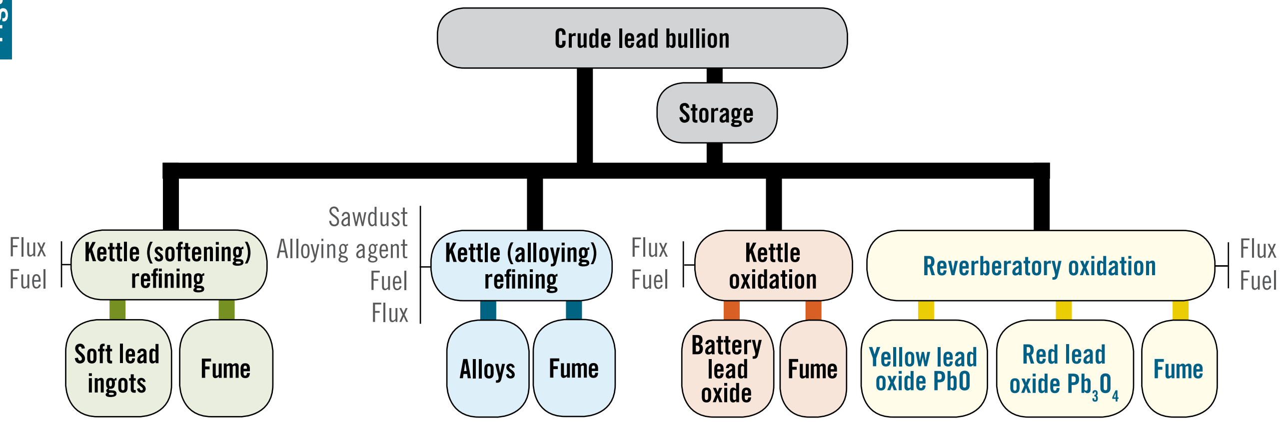
Process Flow for Typical Secondary Lead Smelting: Smelting



Source: Adapted from US Environmental Protection Agency. 1995. *Compilation of air pollutant emission factors. Volume 1: Stationary Point and Area Sources.* Fifth Edition. Chapter 12: Metallurgical Industry. <www.epa.gov/ttn/chief/ap42/ch12/final/c12s11_2010.pdf>

Figure 19

Process Flow for Typical Secondary Lead Smelting: Refining



Source: Adapted from US Environmental Protection Agency. 1995. *Compilation of air pollutant emission factors, Volume 1: Stationary point and area sources.* Fifth Ed. Chapter 12: Metallurgical Industry. <www.epa.gov/ttn/chief/ap42/ch12/final/c12s11_2010.pdf>.

- fines and electrode paste (added directly);
- lead oxide (PbO) produced from the desulfurization of fines and electrode paste;
- flux and reducing agents to provide sufficient chemicals to produce a pure lead bullion;
- lead hydroxide ($Pb(OH)_2$), which is produced when acid electrolyte is neutralized; and
- other sources of lead.

Various types of furnaces are used for secondary lead smelting. The choice of which furnace or combination of furnaces to use depends on the type of feedstock as well as economic variables. In North America, the most common types of furnaces include:[62]

- rotary furnaces,
- reverberatory furnaces,
- blast furnaces,
- electric furnaces,
- rotary kilns, or
- other furnaces.

Some important ESM considerations to minimize and control environmental emissions from secondary lead smelting (lead reduction) operations include:

- desulfurization of fines and electrode paste,
- air pollution control,
- fugitive emission control,
- neutralization of electrolyte solution for lead hydroxide recovery,
- wastewater treatment,
- fluxing agent and slag production, and
- solid waste management.

In North America, most secondary lead smelters are integrated facilities that carry out secondary lead smelting, lead refining and SLAB breaking at the same site. In a few cases, SLAB processors carry out only secondary lead smelting, and then sell the lead bullion to lead refiners who carry out the final step in lead production. Again, there are many benefits to collocating the operations at one location. In addition to the economies of scale that result from integrating pollution control and monitoring processes, collocating lead smelting and refining operations reduces transportation, which in turn helps to minimize emissions from lead-dust and other contaminants.

Pyrometallurgical lead refining is performed with the lead in molten form, which means that crude lead must be melted to temperatures between 327°C (lead melting point) and 650°C (lead boiling point). Lead is heated to a liquid state and various reagents are added at different temperatures to selectively remove undesirable metals from the crude lead. Removal of undesirable metals occurs in the following order: copper, tin, arsenic, and antimony.

62. *Idem.*

5

Pollution Control at Spent Lead-acid Battery Recycling Facilities (Air, Wastewater and Solid Wastes)



5 Pollution Control at Spent Lead-acid Battery Recycling Facilities (Air, Wastewater and Solid Wastes)

Properly managed pollution control mechanisms are one of the best lines of defense to ensure overall environmentally sound management (ESM) in the SLAB recycling industry. This section addresses ESM approaches to pollution control at SLAB recycling facilities, including battery breaking as well as secondary lead smelting facilities. An implementation checklist is provided in Table 15 as a tool to help facilities monitor their ESM implementation status.

5.1 Air Pollution Control Standards for SLAB Recycling Facilities

All stages in the secondary lead recycling process can result in the release of gaseous or particulate emissions, either as point sources through stacks or as fugitive emissions.

- **Stack emissions**: Exhaust gases from an air pollution control device that are released to the atmosphere; and
- **Fugitive emissions**: Untreated emissions that result from material handling, vehicular traffic, wind erosion from storage piles, and other uncontrolled sources.

Lead is the primary pollutant of concern in both stack and fugitive emissions from SLAB recycling facilities, although other pollutants such as SO_2, NO_x and trace quantities of arsenic or volatile organic compounds (VOCs) are monitored in particular locations, depending on local air quality requirements.

Table 5 presents some of the most stringent air emission standards for lead applicable to secondary lead smelters in Canada (Ontario and Quebec, where most SLAB recycling facilities are located), and the United States. It should be noted that Ontario's air standards are based on point of impingement (POI), which is defined as any point on the ground or on a receptor, such as nearby buildings, located outside the company's property boundaries at which the highest concentration of a contaminant caused by the aggregate emission of that contaminant from a facility is expected to occur. Ambient air emissions in Ontario are not regulated; rather, they are part of Ontario's Ambient Air Quality (AAQ) Criteria.

At a minimum, facilities must meet applicable legal requirements for the jurisdiction in which they are located. While the requirements presented in Table 5 and 6 apply broadly at the national, provincial or state level, specific limits may be required at a local level.

In January 2015, Mexico issued an Official Mexican Standard related to the control of atmospheric emissions from secondary lead smelters.[63] The objective of this standard (NOM-166-SEMARNAT-2014) is to set maximum permissible limits of emissions to the atmosphere of lead, total hydrocarbons, nitrogen oxides, and dioxins and furans from the processes of secondary lead smelters or recycling SLABs, including from the corresponding test methods, as well as to set the criteria and specifications for operation. The maximum permissible limits for lead as specified in the standard are outlined in Table 6.

Occupational exposure limits for lead in the three countries are presented in Section 6.

63. NORMA Oficial Mexicana NOM-166-SEMARNAT-2014. Control de emisiones atmosféricas en la fundición secundaria de plomo.

Table 5. **Overview of Most Stringent Air Emission Standards for Secondary Lead Smelters in Selected Jurisdictions in Canada (Ontario and Quebec) and the United States**

Air Emissions	Canada (Ontario[a] and Quebec[b])	United States[c,d]
End of Stack	Quebec: kiln, 30mg/Rm^3; other lead production units 15mg/Rm^3	1.0 mg/m3* max/stack 0.2 mg/m3* facility wide
Point of Impingement (POI)	Ontario: Point of Impingement (POI) standards 0.5 µg/m^3 for 24-hour average and 0.2µg/m^3 for 30-day average	N/A
Fugitive	Ontario and Quebec: Enclosure, negative pressure	Enclosure, negative pressure
Ambient Air	Ontario: 0.5µg/m^3 for 24-hour average and 0.2µg/m^3 for 30-day average Quebec: 0.1µg/m^3 for 1-year average	0.15µg/m3 over 3-month rolling period

Note: All values in this table are based on standard conditions at 1 atmosphere of pressure, dry base, and corrected to seven percent oxygen.

* US end-of-stack emission standards are expressed in mg/dscm (milligrams per dry standard cubic meter), while those in Quebec are expressed in mg/Rm^3 (milligrams per reference cubic meter). At a minimum, facilities must meet applicable legal requirements for the jurisdiction in which they are located.

mg /Rm^3 = milligrams per reference cubic meter; µg = micrograms; N/A = not applicable.

Sources:

a. Ontario Ministry of the Environment. 2012. Ontario's Ambient Air Quality Criteria. <www.airqualityontario.com/downloads/AmbientAirQualityCriteria.pdf>.

b. Government of Quebec, Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (MDDELCC). Clean Air Regulation, Environment Quality Act, chapter Q-2, O.C. 501-2011, s. 164., schedule G. <www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=%2F%2FQ_2%2FQ2R4_1_A.htm>.

c. US Environmental Protection Agency. National Emissions Standards for Hazardous Air Pollutants From Secondary Lead Smelting, 40 C.F.R. sec. 63.543 (a) (2012). <www.gpo.gov/fdsys/pkg/FR-2012-01-05/html/2011-32933.htm>.

d. US Environmental Protection Agency. National Ambient Air Quality Standards (NAAQS). <www.epa.gov/air/criteria.html>.

Table 6. **Air Emissions Standards for Secondary Lead Smelters in Mexico**

Pollutant	Existing Smelters upon Promulgation of New Standard*	Existing Smelters After 4 Years	Existing Smelters After 8 Years and New Smelters upon Promulgation of New Standard*	Measurement Frequency
	MPL			
Lead	14 mg/m^3	2 mg/m^3	0.2 mg/m^3	4 times a year
Nitrogen oxides (NOx)	300 mg/m^3	300 mg/m^3	150 mg/m^3	3 times a year
Total hydrocarbons	140 mg/m^3	140 mg/m^3	70 mg/m^3	3 times a year
Dioxins and furans	0.5 ng/m^3	0.5 ng/m^3	0.2 ng/m^3	1 time a year

Note: All values are based on standard conditions at 1 atmosphere of pressure, dry base, and corrected to seven percent oxygen.
mg = milligrams; m3 = square meters; ng = nanograms.

**Source:* NOM-166-SEMARNAT-2014. Control de emisiones atmosféricas en la fundición secundaria de plomo. <http://dof.gob.mx/nota_detalle.php?codigo=5378252&fecha=09/01/2015>.

5.2 Stack Emission Control at SLAB Recycling Facilities: Technologies and ESM Practices

5.2.1 Overview of Stack Emission Control Technologies

A number of different technologies are available to treat air emissions from secondary lead smelters. A significant amount of research has been carried out to identify which approaches are best for treating these emissions, including practices and controls to protect worker health and the environment. In addition to the technologies and ESM practices presented in these guidelines, readers should also refer to the Occupational Safety and Health Administration (OSHA) Lead Battery Manufacturing eTool as well as the OSHA Secondary Lead Smelting eTool,[64] both of which are excellent sources of guidance on the issues presented in this document.

The approach used to treat air emissions is dependent on particle size. The particulates collected by each of these approaches are generally directed back to the smelting operation where the lead is recycled. The most common technologies used for air pollution control at SLAB recycling facilities include:[65]

- fabric filter or baghouse systems,
- electrostatic precipitators (ESPs),

64. United States Department of Labor n.d.(d).
65. *Idem.*

- wet electrostatic precipitators (WESPs),
- cyclones,
- ceramic filters, and
- wet scrubbers.

Fabric filter or baghouse systems are the most commonly used air pollution control technology in the lead smelting and refining industry as they achieve good performance at reasonable costs. Dust-bearing gas or air is passed through the fabric bags, where the dry particles are captured on the fabric surface.[66] After enough dust has built up on the filter surface (measured by the pressure across the fabric), the filter is periodically cleaned by blowing air back through the fabric, pulsing the fabric with a blast of air, or shaking the fabric.[67] The dislodged dust cake from the fabric filter is moved by gravity to a collection hopper where it is removed. As dust builds up on the fabric, it can act as a filter aid improving the removal efficiency of the fabric filter.[68] Fabric filters/baghouses are generally considered to be a good choice for air pollution control at SLAB recycling facilities and are less expensive to install and operate than ESPs.[69] More information is available in Section 5.2.3.

Membrane filters use a microporous membrane to act as the filter medium.[70] All filterable particulate matter is collected on the membrane surface, and there is no reliance on a filter cake for filtration of particles (as is the case with conventional filter products). There is no penetration of dust into or beyond the membrane filter (as with conventional media) because all filtration takes place on the membrane surface, which acts as the primary dust cake, with no pre-coat required.[71]Membrane surface filtration technology allows the filter fabric to clean better, which leads to longer cleaning times, more "gross" filter cloth area on line, less compressed air usage (savings) and less cleaning stress on the filters (longer life).

ESPs use electrostatic forces to remove particles from air emissions. The Air & Waste Management Association describes them as "relatively large, low velocity dust collection devices that remove particles in much the same way that static electricity in clothing picks up small pieces of lint."[72] High voltage drops between charging electrodes and collecting plates are created through the use of transformers.[73] The electrical field produced by the gas stream as it passes through the high voltage discharge introduces a charge on the particles which are attracted to the collecting plates.[74] Dust is periodically removed from the collecting plates by rapping and is stored in hoppers.

WESPs work in a similar way to ESPs and are similar in design, but are different in that they use water to remove the particles. The wet cleaning process significantly impacts on the nature of the particles that can be captured by WESPs, therefore they can handle a wider range of pollutants and gas conditions than dry ESPs.[75] They are typically used for "polishing" or achieving higher emission reductions in particular circumstances, or in locations with very stringent air pollution control limits. WESPs are particularly efficient for removal of very small particles and can be used as a polishing filter at the outlet of a fabric filter to improve collection efficiency of very small particles. However, this technology is very expensive to operate and is not widely used in the secondary lead smelting industry.[76]

Cyclones are generally used as a primary stage filter for the removal of medium-size and large particulates from air emissions.[77] They do not achieve good removal of small particles and therefore are generally used in conjunction with other air pollution control technologies.

Ceramic filters are used for specialized situations that require removal of small particles from high-temperature gas streams. The ceramic filter is effective in environments that are not suitable for fabric filters because of high temperatures. Ceramic filters also offer good corrosion resistance. The filters are effective across a range of particle sizes, but are most often used when there is a large fraction of $PM_{2.5}$ and submicron particulates.[78]

Wet scrubbers are used at secondary lead facilities mostly to remove sulfur dioxide (SO_2) from stack emissions prior to discharge to the atmosphere.[79] A mechanism similar to a shower is used to spray gaseous emissions with a liquid containing chemicals to neutralize the acid gases. At secondary lead facilities, the emissions contain SO_2, which is neutralized by the addition of an alkaline neutralizing agent.

66. *Idem.*
67. *Idem.*
68. *Idem.*
69. United States Environmental Protection Agency 1977.
70. Donaldson Filtration Solutions n.d.
71. *Idem.*
72. Air & Waste Management Association 2007.
73. *Idem.*
74. *Idem.*
75. Miller 2011
76. Eastern Research Group Inc. 2011
77. *Idem.*
78. Genaidy et al. 2009.
79. Wilson 2002.

5.2.2 Performance and Design Considerations for Stack Emission Control Systems

Most of the text in this section is taken from a publication entitled *Summary of the Technology Review for the Hazardous Air Pollutant Control Technologies in Secondary Lead Smelting: A memorandum on EPA's analysis to identify developments in practices, processes, and control technologies for emissions sources of hazardous air pollutants from the Secondary Lead Smelting source category*.[80] The research presented in the memorandum was commissioned by the United States Environmental Protection Agency (EPA) in 2011 and contains a best practice review for secondary lead smelter air emission control technologies. Where specific text is taken from the EPA material, it is referenced at the end of the paragraph, rather than referencing each sentence.

Figure 20 (taken from the US EPA 2011 memorandum) shows that the average stack outlet lead concentration from the baghouse and WESP combination was significantly lower than the outlet concentration achieved by using baghouses alone. On average, units that employed HEPA filters downstream of a baghouse achieved approximately 20 percent lower outlet lead concentrations than baghouses alone. Many of the fabric filters with the best performance did not have HEPA filters.[81]

The research showed that the factors that correlate best with low outlet lead concentrations are baghouse type, filter material and age of the unit. Recent improvements in baghouse technology have caused baghouses installed after 1997 to perform significantly better than older baghouses. Depending on dust loading and gas characteristics, pulse jet– and reverse air–type baghouses may or may not perform better than shaker baghouses. The filtration material used in the baghouses only affects the lead stack emissions concentration slightly. Proper installation of the bags and properly sealing all ducts and dust conveyance devices are the most critical factors influencing baghouse performance. Additionally, replacing torn bags, rather than repairing them, can significantly improve baghouse performance.[82]

Figure 21 presents emissions from three types of baghouses: shaker, reverse-air and pulse (the terms refer to how the baghouses are cleaned and how lead-contaminated particulates are removed from the filter media). The results show that pulse-type baghouses have the lowest lead concentrations, followed by reverse air and shaker systems.

Figure 22 presents a comparison of lead emissions from baghouses using different filter media. The figure shows that polyester media had the lowest emission concentrations, with Teflon having the highest.[83]

5.2.3 Baghouse Design and Operation[84]

Fabric filters/baghouses are designed around the use of engineered fabric filter tubes, envelopes or cartridges in the dust capturing, separation and filtering process (Figure 23). They can be engineered to address almost any dust producing application under almost any set of circumstances. They are commonly used to control various emission points in lead smelting and refining operations, including emissions from smelting furnaces, kettles, smelting furnace charging points, and smelting furnace taps.

Many designs and operational parameters affect baghouse efficiency, including the bag material, pressure drop, air-to-cloth ratio, type of cleaning, and operating temperature. Many different types of filter media are used, including paper, cotton, polyester, fiberglass, Teflon, GORE-TEX and, in some applications, spun stainless steel.

Bag leak detection systems (BLDSs) are used to detect leaks in the filter bags or other areas within the system. By detecting changes in air pressure, or an increase or decrease in air flow, they can quickly identify when a baghouse filter is not performing effectively. In some locations where stringent air quality standards are in place, particulate sensing is also used for this purpose.

Baghouses are made up of filter media (bags) suspended inside a housing or casing. Fans on the outside of the baghouse or filter media housing draw the polluted air through the filters using negative pressure, capturing the suspended particulate matter and solids on the bags or filter media, and then discharge clean air through the outlet. During the filtering process a layer of particulate matter, called a "dust cake," is formed on the surface of the baghouse bag. The thickness of this dust cake continues to increase until the differential pressure results in decreased capture at the hood or ventilation point; at this point, the bags are cleaned. Depending on the configuration of the baghouse, cleaning of the bags can be done either during operation or offline.[85]

80. Burr et al. 2011.
81. *Idem.*
82. *Idem.*
83. *Idem.*
84. IHS Engineering 360 n.d.
85. *Idem.*
86. *Idem.*

Figure 20

Comparison of Lead Concentration Emissions Achieved by Different Air Pollution Control Technologies

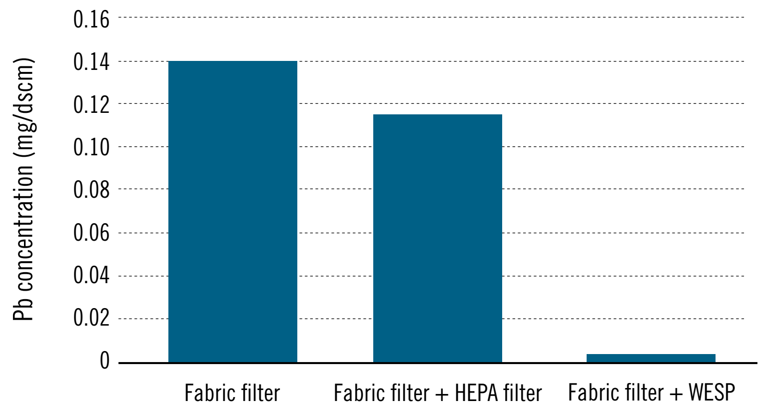


Figure 21

Comparison of Lead Emissions from Different Types of Baghouses

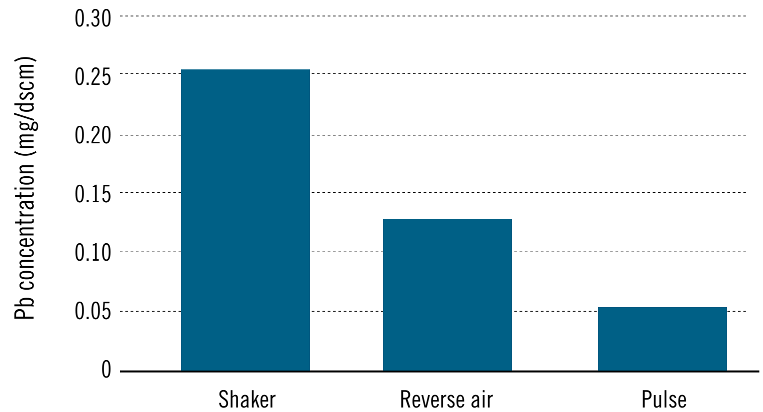
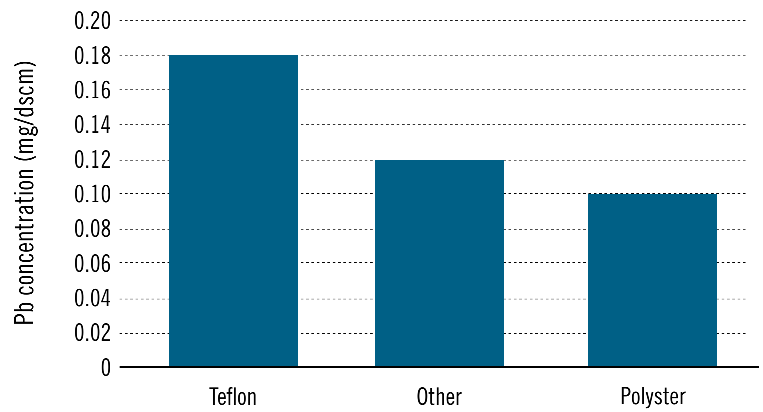


Figure 22

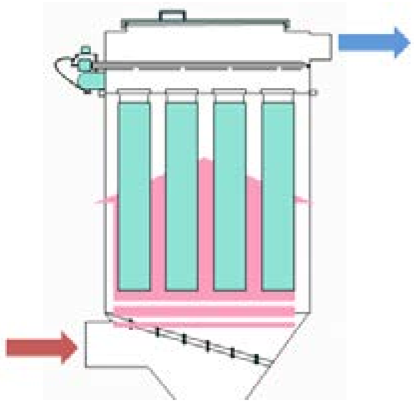
Comparison of Lead Emissions from Baghouses Using Different Filter Media



Note: The data for this analysis originated from a survey of secondary lead smelters in the United States. As a result, it is unclear whether these results correspond to a Teflon fabric or a fabric coated in Teflon.
Pb = lead; mg = milligram(s); dscm = dry standard cubic meter(s).
Source: Burr et al. 2011. *Memorandum to Chuck French, US Environmental Protection Agency: Draft summary of the technology review for the secondary lead smelting source category.* <www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2011-0344-0055>.

Figure 23

Schematic of Baghouse Operation



Note: Red (bottom) arrow indicates dirty air, blue (top) arrow indicates clean (filtered) air.
Source: Neundorfer Inc. n.d. Knowledge base: Baghouse / fabric filter. <www.neundorfer.com/knowledge_base/baghouse_fabric_filters.aspx>.

Dust collected in baghouse filters contains sufficient amounts of lead to be recycled in the lead smelting process. For most bag fabrics (those without a membrane coating), it is the dust cake that does most of the filtering of the particulate matter in the air stream. The thicker the dust cake is, the greater the collection efficiency and pressure drop because the pathways through the bag become finer and also more restrictive. Achieving the right balance between collection efficiency and energy efficiency is key. Overly thorough cleaning or cleaning that is done too frequently can result in lower collection efficiency and possibly a reduced bag life.[86] However, insufficient cleaning will result in greater energy requirements for blower fans (i.e., from high pressure drops) or result in poor collection of emissions.

Although baghouse design is generally the responsibility of the manufacturer, a basic understanding of the most important design criteria is useful for facility operators when making an informed decision on which type of baghouse to use.[87]

The **air-to-cloth** ratio, also known as the superficial filtering velocity, is the most important criterion for baghouse design. It is the volumetric air flow rate in cubic meters per minute (m^3/min) through a dust collector's inlet divided by the total cloth area (m^2) in the filters. The result is expressed in units of velocity (m/min). This ratio determines the airflow capacity of the baghouse and must be optimized to balance the size of the baghouse (capital costs) with the pressure drop (operating costs).[88]

86. *Idem*.
87. Neundorfer Inc. n.d.
88. *Idem*.
89. *Idem*.
90. *Idem*.

The **differential pressure**, or pressure drop, is a measure of the resistance to gas flow in the system. The higher the pressure drop in a baghouse, the more energy that is needed to move air through the system, resulting in increased energy costs. The total differential pressure is calculated as the sum of individual pressure drops due to the fabric, particulate layer (dust cake) and baghouse structure. An abnormally high pressure drop in a baghouse can be caused by a number of factors relating to poor design or setup, including:

- excessive air-to-cloth ratio,
- particulate adhesion caused by excessive moisture in the system, and
- blinded filter bags due to insufficient cleaning energy.[89]

Fabric Filter Media (Bag Materials)[90]

The type of bag material or fabric media is another important part of baghouse design as it determines the life and effectiveness of the filter bag. Bags or filter media can consist of one of a number of different materials. Table 7 provides an overview of the properties of some of these materials used in bag or filter media construction.

Fabric filter media must be compatible both physically and chemically with the gas stream and system conditions. When selecting among various bag/fabric filter materials, facility operators should consider the following factors:

- particle size,
- operating temperature of the baghouse,
- compatibility with gas stream chemistry, including:
  - moisture levels and
  - acidity or alkalinity,
- electrostatic nature of the particles,
- abrasiveness of the particles,
- air-to-cloth ratio,
- fabric's resistance-to-cleaning energy,
- fabric's permeability to allow air to pass,
- fabric's flexibility to allow rippling or stretching, and
- fabric cost.

In addition to the material type, whether the fabric or material is woven will affect the suitability of baghouse systems for different applications. Figure 22 (in Section 5.2.2) shows the relatively superior performance of polyester bags in lead smelting operations. Woven materials have fibers wound in uniform, repeating patterns. This construction is used for low-energy cleaning methods such as reverse air and lower-intensity shakers. The weave space affects the strength of the fabric and the permeability/capture efficiency of the filter. Nonwoven materials

Table 7. **Bag or Filter Media Selection Chart**

Fiber Type	Temperature Limit (dry heat only) (°F/°C)	Resistance to Acids	Resistance to Alkalis	Resistance to Hydrolysis	Resistance to Oxidation
Cotton	180°/85°	poor	good	good	good
PVC	150°/65°	excellent	excellent	excellent	excellent
Polypropylene	190°/90°	excellent	excellent	excellent	poor
Nylon	230°/110°	poor	excellent	good	good
Homopolymer Acrylic	257°/125°	good	good	good	fair
Polyester	300°/150°	good	poor	poor	good
Polyphenylene sulfide (PPS)	375°/190°	excellent	excellent	excellent	fair
Aramid	400°/205°	poor	excellent	poor	fair
Polyimide	450°/235°	fair	fair	good	good
Polytetrafluorethylene (PTFE)	500°/260°	excellent	excellent	excellent	excellent
Fiberglass	550°/285°	good	fair	excellent	excellent

Source: IHS Engineering 360. n.d. Baghouses and baghouse filters information. <www.globalspec.com/learnmore/manufacturing_process_equipment/air_quality/baghouses>.

consist of randomly placed fibers supported and attached to a woven backing. This strong construction is required for high-energy cleaning techniques like pulse jets and aggressive shakers. It should be recognized that results are dependent on dust characteristics and that it may be preferable to use a felt-type material with a membrane in some cases.

Baghouse Cleaning Mechanism[91]

Baghouses are classified according to the methods they use for bag cleaning. There are three different types of baghouse cleaning mechanisms:

- reverse air,
- mechanical shaker, and
- pulse jet.

Each method offers its own advantages for different applications. When selecting a baghouse system, it is important to note that some baghouses incorporate combinations of the above methods (e.g., shaker with reverse air assist). Others may utilize sonic horn technology, which employs high-intensity sound waves to provide additional vibrational energy for dislodging particles.

Figure 24 presents a schematic of a reverse air baghouse. Table 8 presents information on how the reverse air baghouse works and outlines some of the advantages and disadvantages of its design.

91. IHS Engineering 360 n.d.
92. *Idem.*

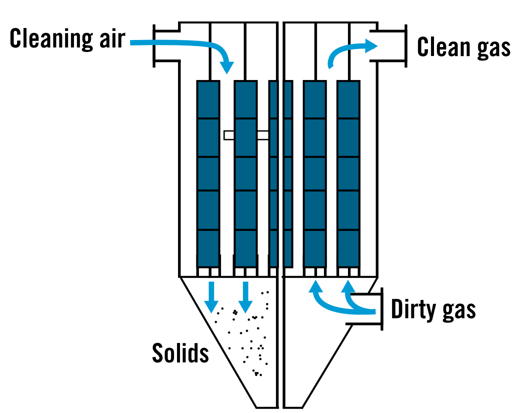
Figure 25 presents a schematic of a mechanical shaker baghouse. Table 9 presents a summary of how the mechanical shaker baghouse works, including some of the advantages and disadvantages of its design.

Figure 26 presents a schematic of a pulse-jet (P/J), or reverse-jet baghouse. Table 10 presents a summary of how the P/J baghouse system works, including some of the advantages and disadvantages of its design.

Baghouse Performance Parameters[92]

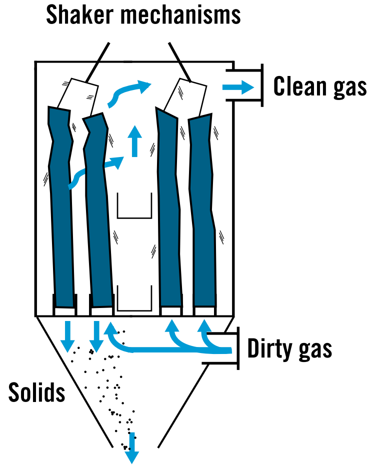
The most important performance specifications to consider when selecting a baghouse are the airflow rating and the minimum particle size.

Figure 24 **Reverse Air Baghouse Schematic**



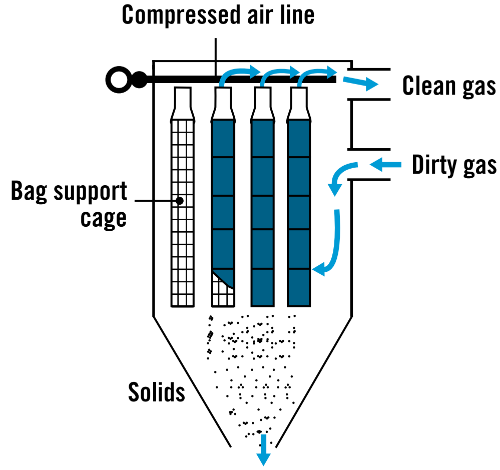
Source: IHS Engineering 360. n.d. Baghouses and baghouse filters information. <www.globalspec.com/learnmore/manufacturing_process_equipment/air_quality/baghouses>.

Figure 25 Mechanical Shaker Baghouse Schematic



Source: IHS Engineering 360. n.d. Baghouses and baghouse filters information. <www.globalspec.com/learnmore/manufacturing_process_equipment/air_quality/baghouses>.

Figure 26 Pulse-Jet (P/J) Baghouse Schematic



Source: IHS Engineering 360. n.d. Baghouses and baghouse filters information. <www.globalspec.com/learnmore/manufacturing_process_equipment/air_quality/baghouses>.

Table 8. **Reverse Air Baghouses: Design/Operation, Advantages and Disadvantages**

Design Features	Advantages	Disadvantages
• Use continuous streams of low pressure air to remove collected solids. • Bags are cleaned by backwashing (reversing the air flow) within a chamber after shutting off the dirty gas flow and isolating the compartment. • Recommended air-to-cloth ratio: 1.75:1 to 2.5:1.	• Usually compartmentalized, allowing sections to be cleaned without shutting off the whole system. • Cleaning action is very gentle, which lengthens bag life. • Preferred for high temperatures due to gentle cleaning action.	• Cleaning air must be clean and dry. • Provides no effective means for removing residual dust buildup. • Requires more maintenance than other types due to dust re-entrainment on the bags.

Source: IHS Engineering 360. n.d. Baghouses and baghouse filters information. <www.globalspec.com/learnmore/manufacturing_process_equipment/air_quality/baghouses>.

Table 9. **Mechanical Shaker Baghouses: Design/Operation, Advantages and Disadvantages**

Design Features	Advantages	Disadvantages
• Use mechanical shaking or vibrating actions to dislodge the filter cake. • Bag bottoms are secured to a plate and their tops are connected to horizontal beams. These beams, driven manually or by a motor, vibrate to produce waves in the bags which shake off particulate matter. • Recommended air-to-cloth ratio: 2.0:1 to 2.5:1.	• Simple design and operation. • Can be compartmentalized to allow sections to be cleaned without shutting off the whole system.	• Cannot operate in temperatures in excess of 500°F (260°C). • More energy- and time- intensive compared to other cleaning methods. • Small amounts of positive pressure inside the bag can significantly reduce collection efficiency. • Large footprint and space requirements. • Requires a large number of bags.

Source: IHS Engineering 360. n.d. Baghouses and baghouse filters information. <www.globalspec.com/learnmore/manufacturing_process_equipment/air_quality/baghouses>.

The **airflow,** or volumetric flow rate, is the acceptable range of gas stream flow rates through the baghouse and is measured in cubic meters per minute (m^3/min) in Canada and Mexico and cubic feet per minute (cfm) in the United States. An increase in gas flow rates causes an increase in operating pressure and an increase in the air-to-cloth ratio. These increases cause more frequent cleanings and high particle velocity, both of which are factors that shorten bag life.

The **minimum particle size,** which dictates the minimum diameter of the particles or particulate matter that the baghouse is capable of filtering, is measured in micrometers. This rating defines the filtering capability of the baghouse.

Table 10. **Pulse-Jet Baghouses: Design/Operation, Advantages and Disadvantages**

Design Features	Advantages	Disadvantages
• Use compressed streams of high pressure air to remove particulate matter. • During cleaning, brief pulses of air are pushed through the bag, dislodging solids, which collect in a hopper below. • Recommended air-to-cloth ratio: 3.25:1 to 4.0:1.	• Can be cleaned while the system is online. • More complete cleaning than shaker or reverse air baghouses, lengthening bag life. • Operates at lower pressure drops and with lower space requirements.	• Requires the use of dry compressed air. • Requires special fabrics for higher temperatures. • Cannot tolerate high moisture levels or humidity in exhaust gases.

Source: IHS Engineering 360. 2015. n.d. Baghouses and baghouse filters information. <www.globalspec.com/learnmore/manufacturing_process_equipment/air_quality/baghouses>.

Other important baghouse operating parameters to consider include:

- **Gas temperature**: Fabrics are designed to operate within a certain temperature range. Temperature fluctuations outside of this prescribed range (even for small periods of time) can weaken, damage, or destroy the bags.
- **Pressure drop**: Baghouses operate best within a certain pressure drop range. This range is based on a specific volumetric flow rate of gas.

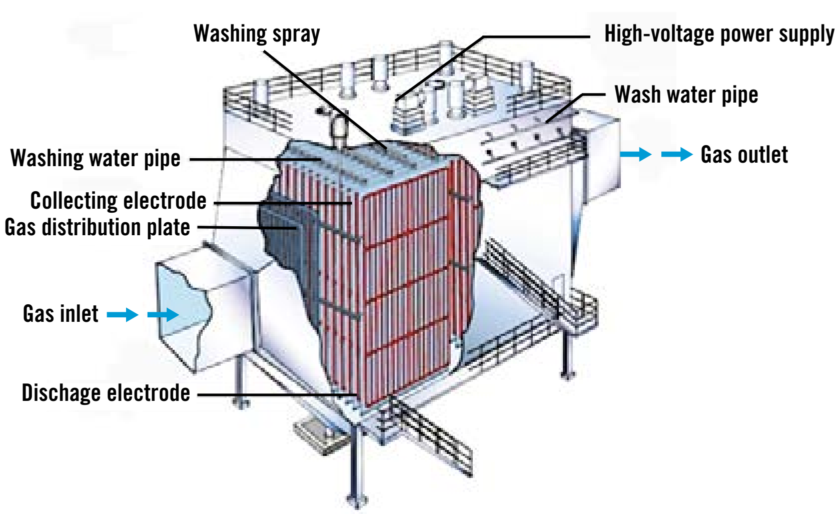
Opacity measures the amount of light dispersion that is caused by the particles in a gas stream. Although not a direct measurement of particle concentration, it is a subjective visual indicator of the amount of dust leaving the baghouse.

5.2.4 Electrostatic Precipitators and Wet Electrostatic Precipitators: Design and Operation

Electrostatic precipitators (ESPs) are widely accepted as an effective system for controlling particulate emissions. ESPs work by creating a high-voltage electrical field (corona) around the discharge electrodes, which causes the gases and the dust particles being carried by the gases to be ionized. The dust particles, once charged, migrate to and deposit themselves on the neutral collecting plates, from which they are dislodged by periodic rapping and guided to dust hoppers for removal.[93] A typical ESP layout is presented in Figure 27.

Figure 27

Typical ESP Layout and Key Components



Source: Henan Kefan Mining Machinery Co., Ltd. 2013. Electrostatic precipitator. <www.kfroastingmachine.com/Auxiliary_Equipment/Electrostatic-precipitator.html>.

93. Henan Kefan Mining Machinery 2013.

Electrostatic precipitation consists of three steps:[94]

- charging the particles to be collected via a high-voltage electric discharge,
- collecting the particles on the surface of an oppositely charged collection electrode surface, and
- cleaning the surface of the collecting electrode.

Dry Electrostatic Precipitators (ESPs)[95]

Dry ESPs consist of a series of parallel vertical plates that act as the collecting electrodes, with a series of discharge electrodes in between the plates spaced some distance apart. As the contaminated flue gas passes through the ESP, negatively charged ions form near the tips of the sharp points of the ionizing electrode (corona discharge).

These negatively charged ions move toward the positively charged collecting electrode surface and charge the contaminated particles passing through the ESP. These charged particles become attracted to the positively charged collection plate, where they accumulate on the surface. The collected particulate builds up on the dry collection surface and forms a layer of particles or "cake" that has insulating properties.

Resistivity becomes a limiting factor to the amount of electrical power that can be achieved within a dry ESP. Dry ESPs perform best when particle deposits on the collecting plates have a resistivity greater than approximately 107 ohm-centimeters (ohm-cm), but less than 2×10^{10} ohm-cm. If resistivity is less than 107 ohm-cm, the electrostatic force holding the dust particles on to the dust layer is too low and re-entrainment of particles in the flue gas can become a serious problem, reducing efficiency. If resistivity exceeds 2×10^{10} ohm-cm, the voltage drop through the particle layer to the grounded electrode becomes significant, lowering field strength in the space between the ionizing electrode and the top of the dust layer. This can cause a breakdown in the electrical field and "back corona" can take place, lowering efficiency.

To dislodge the dust from the collecting electrode surface and into the bottom hopper, mechanical rappers or sonic horns are employed. However, portions of the particles remain suspended in air and get re-entrained in the gas stream. This secondary re-entrainment requires the use of another dry ESP field to collect the re-entrained particulate together with those particles not captured in the first field.

Dry ESPs rely on mechanical collection methods to clean the plates, which require maintenance and periodic shutdowns.

Wet Electrostatic Precipitators[96]

Wet electrostatic precipitators (WESPs) operate in the same three-step process as dry ESPs: charging, collecting and cleaning of the particles. However, cleaning of the collecting electrode is performed by washing the collection surface with liquid, rather than mechanically rapping the collection plates.

The cleaning mechanism affects the nature of the particles that can be captured, the performance efficiencies that can be achieved and the design parameters and operating maintenance of the equipment.

As WESPs operate in a wet environment in order to wash the collection surface, they can handle a wider variety of pollutants and gas conditions than dry ESPs. Also, because WESPs continually wet, the collection surface area and create a slurry that flows down the collecting wall to a recycle tank, the collecting walls rarely build up a layer of particulate cake. This reduces the need for multiple fields, as in a dry ESP where additional fields must be added to capture reentrained particles from the previous field.

Consequently, there is no deterioration of the electrical field due to resistivity, and power levels within a wet ESP can be dramatically higher than in a dry ESP. The ability to inject much greater electrical power within the WESP and the elimination of secondary re-entrainment are the main reasons why a WESP can collect sub-micron particulate more efficiently.

In WESPs, the delivery mechanism for the irrigating liquid is critical to maintain thorough wetting of the collecting electrode surface, in order to avoid corrosion issues without degrading the electrical system.

WESPs are capable of removing particles, droplets and mists as small as 0.01 micron in size up to 99.9+ percent efficiency.[97] Figure 28 presents a picture of a typical WESP.

5.2.5 Sulfur Dioxide Management

Sulfur dioxide (SO_2) emissions are formed when trace amounts of spent acid electrolyte remaining on the lead are introduced to the furnace. Because of their contribution to acid rain, a growing number of countries have initiated tight controls on SO_2 emissions since the early 1990s. Many technologies are available to control these emissions,

94. Altman, R., and W. Buckley. 2003. <http://c.ymcdn.com/sites/www.icac.com/resource/resmgr/MercuryControl_PDF's/CoalGen03_Croll_Hg.pdf>.
95. *Idem*.
96. *Idem*.
97. *Idem*.

Figure 28

Wet Electrostatic Precipitator (WESP)

Source: Envitech Inc. n.d. Wet electrostatic precipitator (WESP). <www.envitechinc.com/wet-electrostatic-precipitator/>.

including dry and wet technologies, which adjust the moisture content of the lead introduced to the process.

One option is to use wet scrubbers, where calcium carbonate reacts with the SO_2 to produce gypsum. Wet scrubbing systems are often used in the secondary lead industry to remove SO_2 at low concentrations. They can also be used to remove particles and to control the temperature (by adiabatic cooling) of the gases entering the baghouse filtration system.[98] Although the basic technology underlying these applications is similar, the design criteria for particulate and gaseous component removal are very different.[99] As a result, wet scrubbing systems are often a compromise between competing objectives.[100] Depending on the priority application, significant cross-media effects, such as the production of additional wastewater, may result.

5.2.6 Maintenance Practices to Control Stack Emissions

Stack emissions at secondary lead processing facilities can be managed through a good inspection and maintenance program. Inspections and routine maintenance should, at a minimum, include the following: [101]

- daily monitoring of pressure drop across each baghouse cell;
- weekly confirmation that dust is being removed from hoppers, through visual inspection or equivalent means of ensuring the proper functioning of removal mechanisms;
- daily check of compressed air supply for pulse-jet baghouses;
- an appropriate methodology for monitoring cleaning cycles to ensure proper operation;
- monthly check of bag cleaning mechanisms for proper functioning, through visual inspection or equivalent means;
- monthly check of bag tension on reverse air and shaker-type baghouses that do not use self-tensioning (spring-loaded) devices;
- quarterly confirmation of the physical integrity of the baghouse through visual inspection of the baghouse interior for air leaks; and
- quarterly inspection of fans for wear, material buildup, and corrosion, through visual inspection or vibration detectors.

Procedures for baghouse maintenance should include, at a minimum, a preventive maintenance schedule that is consistent with the baghouse manufacturer's instructions for routine and long-term maintenance, including the steps listed below:[102]

- inspecting the baghouse for air leaks, torn or broken filter elements, or any other malfunction that may cause an increase in emissions;
- sealing off defective bags or torn filter material;
- replacing defective bags or torn filter material, or otherwise repairing the control device;
- sealing off a defective baghouse compartment; and shutting down the process producing the particulate emissions.

Baghouses equipped with high-efficiency particulate air (HEPA) filters as a secondary filter used to control emissions should be monitored and the pressure drop across each HEPA filter system should be recorded daily. If the pressure drop is outside the limit(s) specified by the filter manufacturer, appropriate corrective measures listed above should be taken.

If a wet scrubber is used to control metal hazardous air pollutant emissions from a process vent, the pressure drop and water flow rate should be monitored at least once every hour. The pressure drop and water flow rate should not fall below 70 percent of the pressure drop and water flow rate measured during initial performance tests.

98. Wilson 2002.
99. *Idem.*
100. *Idem.*
101. United States Federal Register. Environmental Protection Agency, 40 CFR Part 63 – Subpart X. National Emissions Standards for Hazardous Air Pollutants from Secondary Lead Smelting – Final Rule.
102. *Idem.*

5.3 Fugitive Emissions Control at SLAB Recycling Facilities: Technologies and ESM Practices

Fugitive emissions, as the name implies, are emissions that are not treated before discharge or escape to the atmosphere. Fugitive dust emissions can be a significant source of contamination from secondary lead smelters. Fugitive dust source means a stationary source of hazardous air pollutant emissions at a secondary lead smelter that is not associated with a specific process vent or stack.[103] Fugitive dust sources include, but are not limited to, roadways, storage piles, lead-bearing material handling transfer points, transport areas, storage areas, and other process areas and buildings.[104] Fugitive dust emissions may also occur at enclosed facilities when access doors are open and the air from the building escapes to the environment without lead particle removal through an air treatment system.

Control systems to reduce fugitive emissions as much as possible are critical to ESM at secondary lead smelters.

5.3.1 Fugitive Emissions Control

While there are many ways to control fugitive emissions, enclosing areas where fugitive emissions may originate is considered a best practice. The enclosure categories in Table 11 represent the general levels of control found in secondary lead smelters in the United States.

The minimum requirement for control of fugitive emissions is Level 1, where:

- plant roadways are cleaned twice per day;
- in the battery breaking area, storage piles are partially enclosed and wet by twice-daily pavement cleaning;
- furnace, refining and casting areas are partially enclosed and the pavement is cleaned; and
- material storage and handling areas are partially enclosed and are wet for dust suppression, and there are vehicle wash stations at the exits.[105]

Process areas that must be in a total enclosure under US law include:[106]

- smelting furnaces,
- smelting furnace charging areas,
- lead taps,
- slag taps,
- molds during tapping,
- battery breakers,
- refining kettles,
- casting areas,
- dryers,
- material handling areas, and
- areas where dust from fabric filters, sweepings or used fabric filters are processed.

Table 11. **Enclosure Category Definitions**

Enclosure Category	Description
Level 1 Enclosure	Facilities rely primarily on: • enclosure hoods to capture process fugitive emissions, and • partial enclosures with wet suppression for process units and storage areas.
Level 2 Enclosure	Facilities generally employ, in addition to enclosure hoods for process fugitive sources: • a combination of negative-pressure total enclosures, and • partial enclosures with wet suppression for process units and storage areas.
Level 3 Enclosure	Facilities generally employ, in addition to enclosure hoods for process fugitive sources: • negative-pressure total enclosures for all process units and storage areas.

Source: Burr et al. 2011. *Memorandum to Chuck French, US Environmental Protection Agency: Draft summary of the technology review for the secondary lead smelting source category.* <www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2011-0344-0055>.

103. *Idem.*
104. *Idem.*
105. Burr et al. 2011.
106. United States Federal Register. Environmental Protection Agency, 40 CFR Part 63 – Subpart X. National Emissions Standards for Hazardous Air Pollutants from Secondary Lead Smelting – Final Rule.

Figure 29 displays the annual average lead concentrations at ambient monitoring locations around US facilities based on the enclosure category assigned to the facility.[107] Analysis indicates that facilities with Level 3 enclosure that implement the work practices described above are generally achieving much lower lead concentrations from fugitive emissions near their property boundaries.

5.3.2 ESM Strategies to Control Fugitive Emissions

ESM considerations to reduce fugitive emissions at different operations within secondary lead processing facilities are described below.

Storage areas:[108]

- Enclose storage areas to minimize contamination of the surrounding area with lead particle-containing dust.
- Where enclosures are not in place, measures to control fugitive emissions need to be implemented to minimize the spread of wind-blown dust particles.
  - Maintaining low-level moisture in all raw materials or exposed lead pastes will prevent excessive dust generation when moving material within the facility.
  - Inspect non-enclosed stored batteries once each week and move any broken batteries to an enclosure.
- Clean residue from broken batteries as soon as possible.
- Where the storage facility is located in an enclosed building, air exchanges within the enclosed lead battery and raw material storage areas must be managed.
- Fabric filters/baghouses (discussed in Section 5.2 above) are generally used for air pollution control in enclosed storage areas.

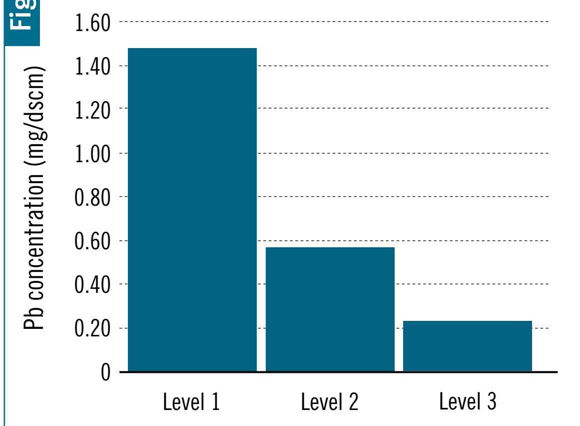
Best housekeeping practices throughout facility operations:[109]

- Clean by wet-washing and/or using a central vacuum system equipped with a HEPA filter and discharge control; clean in a manner that does not generate fugitive lead dust.

107. The figure includes concentration data for 13 US facilities, taken from EPA: <http://www.epa.gov/airdata>.
108. United States Federal Register. Environmental Protection Agency, 40 CFR Part 63 – Subpart X. National Emissions Standards for Hazardous Air Pollutants from Secondary Lead Smelting – Final Rule.
109. *Idem*.
110. *Idem*.

Figure 29

Comparison of Annual Ambient Lead Concentrations for Each Enclosure Category



Note: Pb = lead; mg = milligram(s); dscm = dry standard cubic meters.
Source: Burr et al. 2011. *Memorandum to Chuck French, US Environmental Protection Agency: Draft summary of the technology review for the secondary lead smelting source category.* <www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2011-0344-0055>.

- Immediately clean all affected areas if an accidental release of lead dust is detected, within one hour of occurrence.
- Perform all equipment and other maintenance activities that could generate lead dust in a manner that minimizes emissions of fugitive dust. At a minimum:
- Maintenance should be performed inside an enclosure maintained at negative pressure.
- Used fabric filters should be placed in sealed plastic bags or containers prior to removal from a baghouse.
- Never dry-sweep any process area, as this causes dust to form.
- All lead-bearing material should be contained and covered for transport outside of a total enclosure in a manner that prevents spillage or dust formation.
- Inspect buildings monthly. Repair any new openings within week of discovery.

Surrounding paved surfaces: Dust generated from facility operations will settle on surrounding paved surfaces. Control strategies include:

- Paved and other low-level hard surfaces should be cleaned regularly (twice per day is recommended) using either hand or riding vacuum units to collect existing dust particles and minimize wind-blown dust pollution.[110]
- Use of proper industrial hygiene methods (discussed in Section 6) will also reduce cross-contamination in non-processing areas.

Unpaved areas:[111]

- Unpaved areas should be seeded with ground cover, which will capture dust and minimize wind-blown dust generation; there should be no exposed soils.
- Use dust suppressants on unpaved areas that will not support a groundcover (e.g., roadway shoulders, steep slopes, limited-access and limited-use roadways).
- Unpaved roads should have no more than one vehicle round-trip per day.

Processing operations and process modifications:[112]

- **All processes that could create fugitive emissions**:[113]
  - Total enclosure should maintain negative pressure values of at least 0.013 mm of mercury (0.007 inches of water) at all times and vent to a control device designed to capture lead particulates.
  - Total enclosure should:
  - be free of significant cracks or gaps that could allow release of lead-bearing material; and
  - maintain an inward flow of air through all natural draft openings.
  - Inspect enclosures and facility structures that contain any lead-bearing materials at least once per month.
  - Repair any gaps, breaks, separations, leak points or other possible routes for emissions of lead to the atmosphere as soon as possible.

- **Before furnace operations:**
  - Manage the movement of materials so as to minimize the amount of handling.
  - Blend wet sludges with dry materials to help minimize dust levels.

- **At the furnace and other hot works:**
  - Enclose furnace operations to improve operating efficiency of the ventilation systems.
  - Tap furnace metal into moulds/pots under a ventilated shroud or directly into a bath of covered and ventilated molten lead.
  - Minimize lead emissions during ingot casting by keeping the temperature below 500°C and controlling the flow rate in a manner that reduces dross formation.
  - Fugitive emissions may also occur when materials of different high temperatures are being poured from one vessel to another. Seek to reduce this differential if possible.

- **Ventilation and emission controls systems:**
  - Create and implement detailed procedures for inspection, maintenance, and bag leak detection, and corrective action plans for all baghouses (fabric filters or cartridge filters) that are used to control process vents, process fugitive emissions, or fugitive dust emissions from any source, including those used to control emissions from building ventilation.
  - Capture dusts and fumes by providing local exhaust ventilation that isolates emission sources and filters the air through a baghouse.
  - Ensure that the capture velocity of an exhaust hood is sufficient to prevent fumes or dust from escaping the airflow into the hood. Though the face velocity required to accomplish this will vary from application to application, one meter per second is usually the minimum required.
  - Isolate employees from the exposure hazard, or provide local exhaust ventilation and clean air stations with positive filtered air so employees can be in a clean air station when working in the process area.
  - Best practices for preventing fugitive emissions from emission control systems include:
    - daily monitoring of pressure drop;
    - daily check of compressed air for pulse baghouses;
    - weekly monitoring that dust is removed from baghouses;
    - monitoring of cleaning cycles for proper operation;
    - monthly check of bag tension systems for shaker-style baghouses;
    - quarterly check for leaks and physical integrity of air pollution control devices;
    - quarterly check of all mechanical components operation of continuous leak detection system; mandatory repair/replacement of bags if leaks are detected; and
    - monitoring pressure drop and water flow for scrubbers, operating per manufacturer's recommendation.

- **Vehicles**:
  - Provide vehicles with enclosed cabs that have positive-pressure HEPA filtered air.
  - Wash each vehicle at a wash station inside exit doors from material storage and handling areas. The vehicle wash should include washing of tires, undercarriage and exterior surface of the vehicle, followed by vehicle inspection. This will prevent tracking of contaminants by vehicles to the outside.

111. *Idem*.
112. International Lead Association 2013.
113. United States Federal Register. Environmental Protection Agency, 40 CFR Part 63 – Subpart X. National Emissions Standards for Hazardous Air Pollutants from Secondary Lead Smelting – Final Rule.

- Overall operational considerations:
    - Modify the plant layout in a way that reduces the amount of materials handled and transported from one part of the process to the next.
    - If at all possible, contain the whole process in one enclosed building and separate one operation from another to prevent cross-contamination in the event of a rogue emission.
    - If possible, use mechanical means to perform tasks with a high exposure risk in order to minimize possible exposure pathways.
    - Wash down areas with water on a regular basis and keep working surfaces damp.
    - Operator training, prudent working practices and good housekeeping when operating mobile equipment should all address fugitive dust considerations.
    - Ensure respiratory protection is available to employees involved in processing and subject to exposure. Respirators may come in the form of a mask or the filtered air helmet. If sulfur is present, carbon filter combinations are required.
    - Place properly maintained belt wipes on a tail pulley on conveyors, skirting and curtains, at the head of any belt drive system.

- **As part of the facility's Environmental Health and Safety Management System (EH&SMS):**
    - Assess the risks of each process and establish mandatory safety procedures for each task.
    - Establish monitoring, inspection and maintenance regimes wherein engineering controls are provided to minimize or contain fugitive lead emissions.
    - Create and implement a list of specified standard operating practices specifically designed to minimize fugitive emissions.
    - Observe service intervals that are specified in the facility's EH&SMS, are recommended by equipment manufacturers, and/or comply with a statutory regulation.
    - Maintain an up-to-date record of all inspections and engineering maintenance work that has been done at the facility.[114]

5.4 Management of Spent Acid Electrolyte and Wastewater Treatment

Spent acid electrolyte is a powerful acid and contains considerable amounts of lead.

Options to treat spent acid electrolyte vary by SLAB recycling operation and include processes to recover different materials for re-use, or—at a minimum—to create an effluent that will not harm the environment. The options for management of acid electrolyte include:

- purifying the electrolyte so that it can be recovered and re-used; or
- if recovery and recycling of the electrolyte is not viable, then, at a minimum, neutralizing prior to additional handling.

The best decision on ESM of spent electrolyte depends on facility-specific circumstances.

5.4.1 Electrolyte Re-use and Recycling

Spent electrolyte is re-used at some facilities. The economic viability of acid re-use will depend on the volume of acid managed, the location of the facility, and the shipping distance to the battery manufacturer.

Impurities are removed from the spent electrolyte using liquid-liquid extraction or other technologies, and concentrated sulfuric acid is added to the purified electrolyte to bring it up to a strength suitable for use as electrolyte in new batteries.

Re-use of spent electrolyte is only viable if recycling occurs near a battery manufacturing facility or at the same site so that the acid can be used without much transportation. If transportation of acid is required, the economics of acid re-use are not viable.[1165]

114. *Idem.*
115. Australian Battery Recycling Initiative n.d.

5.4.2 Wastewater Management

Wastewater is generated from operations throughout the lead-acid battery breaking, smelting and refining processes. Most of the wastewater in integrated facilities comes from the battery breaking operation. Other sources of wastewater include water from scrubbers, cleaning, maintenance, chillers, process equipment, and air compressors. The nature and volume of wastewater will vary by facility. If not re-used within operations, wastewater is treated before discharge.

Wastewater from SLAB recycling operations includes spent acid electrolyte as well as process water, re-used water and cleanup water from plant maintenance and operations. SLAB facilities require wastewater treatment systems to manage effluents from spent acid electrolyte treatment systems, and all surface water that may be contaminated by lead particles, as well as spills and floor drainage, which should be directed to the wastewater treatment system and be treated prior to discharge.

There are several environmentally sound strategies for managing wastewater; the method chosen depends on the toxicity of the wastewater, regulatory requirements, and the possibility of capturing value from components processed out of the wastewater. These strategies include the following:

- Neutralize wastewater through pH adjustment by addition of magnesium hydroxide ($Mg(OH)_2$) or a similar buffering agent. Iron co-precipitate can also be used for metal removal during neutralization. Depending on the facility location, the precipitate from the adjustment/neutralization is filtered through a press and the remaining liquid discharged to a sewer or an existing waterbody, in accordance with local requirements. Acceptable lead concentrations in discharged wastewater vary depending on local conditions and are generally stipulated by local regulatory authorities.
- Conduct leachate testing on the resulting filter cake to determine its hazardous contents. Leachate testing will determine composition and metal content of the filter cake and should be conducted via analytical tests at a certified laboratory. Depending on outcome, it should be disposed of either as a hazardous waste to a licensed hazardous waste facility or as a non-hazardous waste at a landfill.

5.5 Solid Waste Management at SLAB Recycling Facilities: Slag, Polypropylene, and Other Solid Waste

Various solid wastes are produced at secondary lead processing operations. These include:

- slags,
- plastics and cardboard, and
- other wastes, such as contaminated PPE, HEPA filters, used spill kits, and baghouse bags.

5.5.1 Management of Discard Slag

Slags are a solid waste produced in the furnace. The physical and chemical properties of the slag and the most appropriate management option depends on the fluxing agent used as well as the lead smelting process used.[116]

Slags tapped from the furnaces are cooled and separated into two categories.[117] The first is called matte, which in some cases can be re-used in the feed stream to the furnaces, but if it is high in iron and sulfur then it is discarded. The remaining slag material is stabilized and disposed of as waste in either a hazardous or non-hazardous waste landfill, depending on the results of leachate testing. At some locations, lead sulfate paste is de-sulfurized by reacting it with a variety of chemicals, depending on which process is used to produce lead oxide (PbO). This procedure reduces slag formation and in some cases reduces the amount of SO_2 released into the air. The decision to de-sulfurize (which costs more, but results in lower air emissions and lower slag formation) is location- and facility-specific. In all cases, the slag should be tested to determine how it should be classified, in order to develop an appropriate slag management plan.

It is considered a best practice not to re-use slag for construction or other applications so as to avoid future liability concerns.

5.5.2 Recycling of Polypropylene and Other Solid Waste

SLABs contain a number of constituent components and materials, most of which are readily recyclable, including:

- polypropylene plastics,
- other plastics, plate separators, small amounts of ebonite (on occasion), and
- cardboard.

116. Secretariat of the Basel Convention 2003.
117. *Idem.*

Polypropylene plastic generated from battery recycling can be recycled, although there may be high levels of metal (lead) contamination. This recycled resin is re-used mostly in the battery industry for new cases.

Other plastics and plate separators are disposed of as hazardous waste due to high levels of metal contamination. The material is managed through stabilization or microencapsulation through a waste management facility, then landfilled at either a hazardous or non-hazardous waste facility, depending on local requirements.

Ebonite's occurrence in SLABs is minimal. When it is present, the material is handled in the same way as polyethylene separator material; it is combusted in the furnaces along with the lead feed, or sent off-site for disposal.

Contaminated cardboard (referred to in the recycling business as OCC—old corrugated cardboard) should be leachate-tested to determine appropriate disposal options.

Separate management plans should be developed for other wastes, such as contaminated PPE, HEPA filters, used spill kits, and baghouse bags. In general, these wastes are disposed of through the furnace operation. The appropriate management option will depend on the results of leachate tests.

5.6 Decommissioning and Closure of SLAB Facilities

SLAB facilities will occasionally be closed or relocated. In these situations, a decommissioning plan is required and should be developed, implemented and properly documented as part of ESM. Most facilities already have a decommissioning plan in place as a regulatory requirement, and some updates may be needed when implementing the decommissioning phase. Sufficient insurance coverage should be established to address ongoing post-closure protection.

Decommissioning and closure projects typically involve the following activities (among others):

- decontamination and demolition of various buildings (e.g., battery breaking, maintenance, and storage buildings, including infrastructure such as piping and drains) and equipment (e.g., processing equipment such as furnaces and conveyors, and pollution control equipment such as fabric filters/baghouses, wastewater treatment plant, tanks, stormwater storage ponds) used in the battery recycling process;
- testing and disposal of material to be removed off-site; and
- documentation of decommissioning and demolition activities and post-closure test results.

The project work plan should be developed to include the following:

- A **Decontamination and Demolition Work Plan** to address the following issues:
  - site preparation,
  - schedule of work activities,
  - site laydown areas, and
  - management and disposal of materials generated from the decommissioning and demolition activities.

- A **Health and Safety Plan** to address the following:[118]
  - communications system,
  - employee training,
  - chemical hazards,
  - site traffic,
  - emergency evacuation,
  - accident investigation, and
  - personal protective equipment (PPE).

- A **Dust Control and Air Monitoring Plan** incorporating:
  - an **Air Monitoring Plan** outlining location and frequency of sampling and parameters to be monitored; and
  - a **Dust Control Plan** outlining dust-suppression practices, approaches and equipment to be used during the decommissioning and closure project, and locations of dust suppression equipment installations to control emissions during the project.

- A **Project Close-out Report** to document the following:[119]
  - air-monitoring information, including sampling and analysis records;
  - waste-tracking information, including manifest numbers, trucks, destinations, weights and dates;
  - safety statistics, including person-hours, job safety analysis, inspections and incident investigations;
  - wind monitoring, including baseline conditions and routine monitoring results;
  - weekly status reports;
  - photographic documentation of project progress; and
  - copies of executed notifications and permits.[120]

118. Pastor, Behling & Wheeler, LLC, and Remediation Services, Inc. 2012.
119. *Idem.*
120. *Idem.*

5.6.1 Soil Remediation Standards

In Canada, soil quality guidelines (SQG) are derived for different land uses, following the process outlined by the Canadian Council of Ministers of Environment (CCME), using the different receptors and exposure scenarios for each land use. These guidelines for industrial land use are presented in Table 12.

In Mexico, the maximum permissible limits for contaminants in soil, including lead, are established in NOM-147 (*Norma Oficial Mexicana* NOM-147-SEMARNAT/SSA1-2004), the Mexican Official Standard used to address heavy metals contamination.[121] Under NOM-147, when detected levels of metals exceed established limits, the site is considered contaminated and requires remediation.[122] Although the standard presents four options for determining the cleanup level, the most commonly used method requires that soil remediation be performed to attain lead total reference concentrations (TRCs), based on land use, as shown in Table 13.

In the United States, the US EPA Final Rule on lead defines lead-contaminated soil as "bare soil on residential real property that contains lead at or in excess of levels determined to be hazardous to human health."[123] Under this rule, soil lead levels up to 400 ppm are considered as "requiring no action" while levels between 400 and 1200 ppm are considered a "level of concern." The current hazard standard is anything above 1,200 ppm. This is not the "cleanup level" but an indicator that further study is needed. Table 14 shows recommended actions for different levels of soil lead contamination.[124]

Table 15 provides a checklist of environmentally sound management activities and the corresponding actions to be considered, and identifies the location in section 5 above where these are discussed. **In addition to national/federal standards, it is noted that some local regulatory bodies apply more stringent criteria at the state or provincial level.**

Table 12. **Canadian Soil Quality Guidelines (SQG) for Lead**

	SQG for Industrial Land Use (mg/kg)
Guideline	600*
SQG_{HH} Limiting pathway for SQG_{HH}	740 Off-site migration
SQG_E Limiting pathway for SQG_E	600 Soil contact
Interim soil quality criterion (CCME 1991)	1,000

Note: SQG_{HH} = soil quality guideline for human health; SQGE = soil quality guideline for environmental health.

* Data are sufficient and adequate to calculate an SQGHH and an SQGE [thus calculation of a provisional SQG_{HH} and SQG_E was not necessary]. Therefore, the soil quality guideline is the lower of the two and represents a fully integrated *de novo* guideline for this land use, derived in accordance with the soil protocol (CCME 1996a). The corresponding interim soil quality criterion (CCME 1991) is superseded by the soil quality guideline.

Source: Canadian Council of Ministers of the Environment. 1999. *Canadian soil quality guidelines for the protection of environmental and human health.* <http://ceqg-rcqe.ccme.ca/download/en/269>.

Table 13. **Mexican Total Reference Concentrations (TRCs) of Lead, by Land-Use Type**

	Total Reference Concentration (TRC) (mg/kg)
Agricultural/Residential	400
Commercial/Industrial	800

Source: Maggio, A.J. 2010. Mexico: Environmental due diligence and the Mexican Waste Law. <http://ehsjournal.org/http:/ehsjournal.org/anthony-j-maggio/mexico-environmental-due-diligence-and-the-mexican-waste-law/2010/>.

Table 14. **United States Bare-Soil Lead Hazard Identification**

Soil Lead Level (parts per million)	**Recommended Interim Action**
> 1,200 (hazard standard)	Eliminate hazard: remove contaminated soil or install permanent covering
400–1,200 (level of concern)	Implement interim controls: cover bare soil; use doormats in entryways; wash hands and toys more frequently
<400	No action

Source: US Environmental Protection Agency. 2001. *Lead-safe yards: Developing and implementing a monitoring, assessment, and outreach program for your community.* <www.epa.gov/region1/leadsafe/pdf/chapter3.pdf>.

121. NORMA Oficial Mexicana NOM-147-SEMARNAT/SSA1-2004, Que establece criterios para determinar las concentraciones de remediación de suelos contaminados por arsénico, bario, berilio, cadmio, cromo hexavalente, mercurio, níquel, plata, plomo, selenio, talio y/o vanadio. [Which establishes criteria to determining the concentrations for remediation of soils contaminated by arsenic, beryllium, cadmium, hexavalent chromium, mercury, nickel, silver, lead, selenium, thallium and/or vanadium.]
122. Maggio 2010.
122. *Idem*.
123. United States Federal Register. 40 CFR Part 745 Lead; Identification of Dangerous Levels of Lead; Final Rule. Part III.
124. United States Environmental Protection Agency 2001.

Table 15. **Implementation Checklist for Pollution Control at SLAB Recycling Facilities**

Implementation Area	Key ESM Activity	Actions and Considerations	For details, see the listed section above
Air pollution controls to reduce fugitive emissions	Meet regulatory requirements for air emissions	☐ Know the facility's jurisdictional regulatory limits for air emissions and use appropriate technology to meet them	§5.1
	Stack emissions air pollution control equipment and operations	☐ Identify, install, and operate correct technology for capturing particles in stack emissions, based on particulates' profile and operational parameters	§5.2
	Fugitive emissions controls	☐ Enclose areas where fugitive emissions may originate, using optimal Level 1, 2, or 3 Enclosure, as appropriate (see Table 11)	§5.3.1
		☐ In storage areas: ☐ Keep raw materials and exposed lead pastes moist to prevent lead-contaminated dust movement ☐ Clean residue from broken batteries ☐ Throughout facility: ☐ Clean with wet wash or special vacuums ☐ Never dry-sweep ☐ Clean up after accidents within one hour ☐ Perform any activity that could release lead dust under negative pressure ☐ Load lead-bearing materials for transport indoors ☐ Clean surrounding paved areas twice daily with vacuums ☐ Non-paved areas: ☐ Seed with ground cover to reduce wind-blown dust ☐ Use dust suppressants if no groundcover ☐ One vehicle round-trip per day on unpaved roads	§5.3.2
Reduce fugitive emissions in all **processing areas**	Any process that could create fugitive emissions	☐ Maintain negative pressure throughout facility, and vent to control device capturing lead particles ☐ Total facility enclosure: ☐ Ensure no cracks or gaps can release lead-bearing material ☐ Maintain inward flow of air	§5.3.2
	Before furnace operations	☐ Minimize the movement and handling of materials between areas ☐ Blend wet sludges with dry materials to reduce dust	§5.3.2
	Furnace, hot works safety	☐ Enclose furnace to improve efficiency of ventilation ☐ Attend fugitive emissions from metal-pouring, molding or casting areas with shrouding, enclosures, temperature and other operational controls	§5.3.2
Best practices to reduce fugitive emissions throughout facility	Ventilation and emission controls systems	☐ Regularly inspect, maintain, and repair all emission-control equipment ☐ Capture dusts and fumes in baghouse ☐ Ensure exhaust hoods are working properly to prevent fume or dust escape ☐ Provide local exhaust ventilation and clean air stations with positive filtered air for employees in process areas	§5.3.2
	Regular and periodic maintenance	☐ Daily – monitor pressure drop, check baghouse compressed air, monitor facility cleaning cycles ☐ Weekly – monitor dust removal from baghouses; inspect building for cracks or gaps and seal immediately ☐ Monthly – check baghouse systems ☐ Quarterly – check for leaks in all air pollution control systems; review all mechanical components of continuous leak detection systems; repair/replace if needed ☐ Scrubbers – maintain per manufacturer recommendations	§5.3.2
	Vehicles	☐ Enclose vehicle cabs with positive-pressure HEPA-filtered air ☐ Wash using lead-control protocols	§5.3.2
	Overall operational ESM activities	☐ Design facility to minimize materials-handling ☐ Manage air exchanges between areas to prevent fugitive emissions ☐ Enclose process in one building if possible ☐ Keep work surface damp; wash work areas with water regularly ☐ All training and housekeeping practices must address fugitive dust control strategies ☐ Provide respiratory protection to workers exposed to lead ☐ Include belt wipes on conveyors	§5.3.2

Table 15. (continued)

Implementation Area	Key ESM Activity	Actions and Considerations	For details, see the listed section above
Overall operations	Implement Environmental Health & Safety Management System (EH&SMS)	☐ Create and implement a facility-wide EH&SMS ☐ Assess and document all risks that may create air pollution or fugitive emissions ☐ Design and implement safe Standard Operating Procedures for all activities ☐ Follow all service intervals as specified by the EH&SMS, regulatory requirements, and manufacturer specifications	§5.3.2
Spent acid electrolyte and wastewater treatment	Spent acid electrolyte management	☐ Select appropriate treatment method for spent acid electrolyte	§5.4
	Wastewater management	☐ Select appropriate treatment method for process wastewater, based on toxicity, regulatory requirements, and recovery value ☐ Conduct leachate tests on remaining filter cake	§5.4
Facility solid waste	Solid and hazardous waste management	☐ Slag management is based on type of fluxing agent used; dispose of as solid or hazardous waste, depending on leachate test results	§5.5.1
		☐ Polypropylene plastic from battery cases may be recycled, depending on lead content ☐ Dispose of other plastics and plate separators as hazardous waste due to high metals content	§5.5.2
Facility Decommissioning and Closure	If the SLAB facility is to be closed	☐ Develop detailed project work plan, covering: ☐ Site decontamination and demolition ☐ Health and safety plan ☐ Dust control and air monitoring plan ☐ Soil remediation	§5.6 - §5.6.1

6 Monitoring and Environmental Protection at Spent Lead-acid Battery Recycling Facilities



6 Monitoring and Environmental Protection at Spent Lead-acid Battery Recycling Facilities

The key to success of any ESM program is to monitor operational performance on a continuing basis. Monitoring results provide the information and feedback needed for continuous improvement. It is important to have a remedial action plan for situations in which monitoring discovers practices that are not effective or have not been implemented properly. This section addresses four key aspects of ESM performance at SLAB recyclers:

- occupational health standards;
- the use of personal protective equipment (PPE) and implementation of safe work practices;
- control measures and practices that minimize accidents and exposures; and
- monitoring systems to track performance and progress of the ESM program.

6.1 Occupational Health Standards

Just as the rules pertaining to SLAB collection, handling and transportation vary between the three North American countries, so do the standards surrounding occupational health. Depending on the jurisdiction, three different occupational health protections measurements as specified in regulatory standards might be applied to protect employees of secondary lead smelters: permissible exposure levels (PEL), action levels (AL), and blood lead levels (BLL). Each of these is described in brief below:[125]

- **Permissible exposure level (PEL):** The concentration of lead in the air above which employers are required to have their employees wear respirators and protective clothing, and must ensure that certain housekeeping and hygiene practices are in place.
- **Action level (AL):** The concentration of lead in the air above which employers must establish a medical surveillance program that includes testing the BLLs of all employees.
- **Blood lead level (BLL):** If a worker's BLL exceeds a certain threshold, the employer must take certain steps.

Table 16 presents a summary of some of the occupational health and safety standards for lead that apply to secondary lead smelters in Canada, Mexico, and the United States, and the non-occupational health lead standards that apply to children and to pregnant and lactating women.

Secondary lead smelters must be aware of the applicable occupational health standards and have a robust system in place to monitor conformity to these standards. This ensures both regulatory compliance and protection of human health.

6.2 Control Measures to Minimize Exposures: Administrative and Engineering Controls

Control measures are a series of actions that can be implemented to reduce the severity or frequency of an undesirable situation or outcome. If properly implemented, they can significantly reduce the risk of environmental exposures and environmental contamination resulting from SLAB recycling operations.

Deciding on the appropriate control often involves carrying out a risk assessment to evaluate and prioritize the hazards and risks.[126] Risk assessment is a systematic process wherein the severity of the hazard and its potential outcomes are considered along with other factors, including exposure level and the number of persons exposed and the risk of that hazard being realized.[127] There are three basic steps involved in conducting a risk assessment:[128]

125. Commission for Environmental Cooperation 2013b.
126. Canadian Centre for Occupational Health and Safety 2015a.
127. Health and Safety Authority n.d.(a).
128. Health and Safety Authority n.d.(b).

1. **Identify the hazards.** A hazard can be defined as anything that has the potential to cause harm to human health or the environment. For example, working with spent acid electrolyte or transporting SLABs can pose hazards. Sample questions to ask include:
   - What are the potential exposure hazards and by what method are workers exposed (e.g., inhalation, ingestion)?
   - Where is the source of the hazard?

2. **Identify the level of risk for each hazard.** Risk level is determined by the likelihood of harm occurring, coupled with how severe the harm could be. Sample questions to ask include:
   - Who could be harmed? Would it be employees, members of the surrounding community, families of facility employees? Consider vulnerable groups (e.g., young people, the elderly, pregnant employees).
   - When are the highest/lowest exposure times and does the exposure level vary during a workday?
   - Looking at facility data, note if there is exposure at or above ALs or PELs. What does this indicate about the risk?

3. **Identify the controls or improvements that need to be put in place to avoid or reduce the risk.** Sample questions to ask include:
   - How can the source of emissions be controlled using mechanical applications, administrative policies/procedures or control measures?

Control measures are the most significant part of the risk assessment, as they set out the actions that must be followed to protect human health and the environment. Some control measures may already be in place, while additional measures may be needed.[129] Employers and facility operators can use the information from a risk assessment to make informed choices about which control measures to select and implement.

The main ways to control a hazard at SLAB recycling facilities are presented in Figure 30. The first two—engineering controls and administrative controls—are described below. Personal protective equipment (PPE) is discussed in Section 6.3.1.

Table 16. **Select Lead Standards in Canada (Ontario and Quebec), Mexico, and the United States**

Occupational	**Canada**[a, b]	**Mexico**[c,d,e]	**United States**[f]
Permissible airborne exposure	**Ontario**: 50 µg/m³ per 8-hour exposure **Quebec**: 50 µg/m³ per 8-hour exposure	50 µg /m³ averaged over 8 hours per day, 40 hours per week	50 µg/m³ averaged over 8-hour period
Blood lead levels (BLLs)	**Ontario**: medical removal limit is 69.966 µg/dL **Quebec**: medical removal limit is 40 µg/dL	30 µg/dL for men, 10 µg/dL for women (see note)	Medical removal: 60 µg/dL, or 50 µg/dL over an extended time period; industry voluntary standard for removal at 40 µg/dL
		Non-occupational	
BLLs of concern in children	10 µg dL	10 µg dL	5 µg/dL—reference based on the 97.5th percentile of population; no longer using BLL terminology
BLLs of concern in pregnant and lactating women	10 µg dL	10 µg dL	10 µg/dL

Note: Although Mexico does not have a medical removal requirement for BLL, NOM-010-STPS-2014 stipulates that employers are required to conduct biological monitoring of their workers and provide evidence that they have taken action with the workers if chemicals in the work environment exceed the permitted limits. Health authorities and occupational health and safety authorities can coordinate epidemiological surveillance programs for workers health in SLAB facilities. The results of epidemiological surveillance, blood lead levels and of the performed evaluations must be publicly available at least in a yearly report, according to each country's regulations. In addition, this information must be delivered to each worker through printed reports.

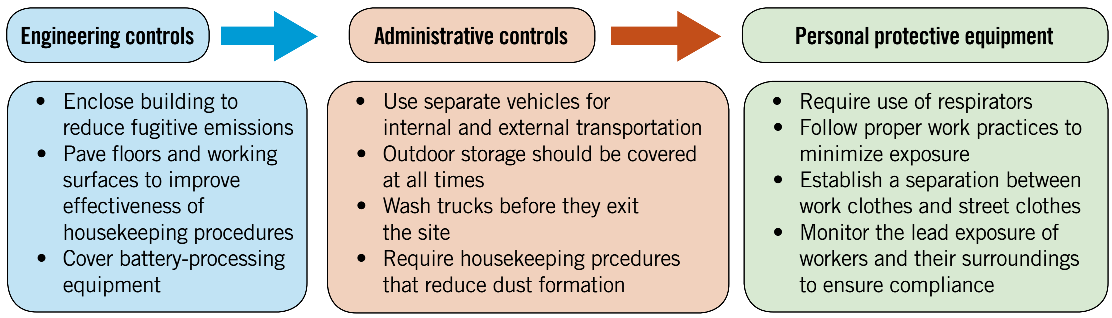
Note: µg = microgram(s); m³ = cubic meter(s); dL= deciliter.

Sources:

a. Ontario Regulation 833, as amended 149/12 (2013). <www.e-laws.gov.on.ca/html/regs/english/elaws_regs_900833_e.htm>.
b. O.C. 885-2001, s. 45, Regulation Respecting Occupational Health and Safety, R.S.Q., c. S-2.1, s. 223, Div. VI, Individual Protective Respiratory Equipment, O.C. 885-2001, s. 45 (2001), <www2.publicationsduquebec.gouv.qc.ca/dynamic-Search/telecharge.php?type=3&file=/S_2_1/S2_1R13_A.HTM>.
c. NORMA Oficial Mexicana NOM-010-STPS-2014, Agentes químicos contaminantes del ambiente laboral – Reconocimiento, evaluación y control. <http://trabajoseguro.stps.gob.mx/trabajoseguro/boletines anteriores/2014/bol056/vinculos/NOM-010-STPS-2014.pdf >.
d. NORMA Oficial Mexicana NOM-047-SSA1-2011, Salud ambiental-Indices biológicos de exposición para el personal ocupacionalmente expuesto a sustancias químicas. <http://dof.gob.mx/nota_detalle.php?codigo=5249877&fecha=06/06/2012>.
e. SSA, NOM-199-SSA1-2000, Salud ambiental. Niveles de plomo en sangre y acciones como criterios para proteger la salud de la población expuesta no ocupacionalmente. <www.salud.gob.mx/unidades/cdi/nom/199ssa10.htm>.
f. United States Federal Register. 40 CFR Part 63. National Emissions Standards for Hazardous Air Pollutants from Secondary Lead Smelting – Final Rule.

129. *Idem*.

Figure 30 Examples of Control Measures to be Implemented at Secondary Lead Smelters



Source: Adapted from Canadian Centre for Occupational Health and Safety. 2014a. OSH answers fact sheets: Hazard control. <www.ccohs.ca/oshanswers/hsprograms/hazard_control.html>.

6.2.1 Engineering Controls

Engineering controls involve redesigning a process in a way that removes or reduces the hazard to the person. Examples of specific engineering controls that should be implemented in SLAB recycling facilities include the following:

- **Carry out breaking, reduction and refining operations in enclosed buildings:** Carrying out operations in enclosed buildings will minimize the potential for uncontrolled air emissions from the SLAB operation. When carried out in enclosed buildings, dusts can be treated by a baghouse or other air filtering system, thus protecting the environment from contaminated particles containing lead and other particulates.
- **Pave all floors used for outdoor storage**: All other work surfaces should have a smooth, impermeable surface. This facilitates good housekeeping practices like vacuuming dust particles, as well as spill containment and washing of surfaces where required. Paved areas should be designed in such a way that all liquid runoff will be collected in a central location for further evaluation.
- **Cover conveyors and other processing systems**: Conveyor systems should be enclosed as much as possible to minimize the uncontrolled release of dust and lead particles.

6.2.2 Administrative Controls

Administrative controls include measures such as adopting standard operating procedures or safe work practices, or providing appropriate training, instruction or information to reduce the potential for harm and/or adverse effects to human health and/or the environment.[130]

Specific examples of administrative controls that should be implemented at SLAB recycling facilities include:

- **Cover trucks transporting material within the site.**
- **Separate internal and external vehicles:** Vehicles used on-site only should have a regular maintenance and cleaning schedule to keep contamination from collecting.
- **Lead-containing items and materials stored/staged outside should be covered and surrounded by secondary containment.**
- **Wash trucks before they exit the site.**
- **Keep operations wet to avoid dust formation:** Any material handling (manually or by machine) should be executed with care to reduce dust generation.
- Collect rainwater and surface water runoff.

6.3 Proper Work Practices

Workers at SLAB recycling facilities need to protect themselves from lead particles and other contamination while at work. They also need to protect their families and the surrounding environment, by not tracking lead particles home from their work place. Work practice controls reduce the potential exposure to lead by changing the manner in which a task is performed.[131] Several work practices have been identified that minimize workers' and the surrounding community's exposure to lead. These are presented in Table 17. Details on personal protective equipment (PPE) such as respirators and appropriate clothing follow in Section 6.3.1.

Additional work practices that help to minimize employee exposure to lead particles and also to minimize the tracking of lead particles outside the secondary lead recycling facility to the outside environment (and possibly to the homes of employees, where workers' families can be exposed to lead particles), include the following:[132]

130. Health and Safety Authority n.d.(a).
131. Acello 2002.

Table 17. **Proper Work Practices for Implementation in SLAB Recycling Facilities**

#	Work Practice	Rationale
1	• Do not smoke	Decreases the body's ability to process heavy metal contamination
2	• Segregate work and eating areas	Minimizes ingestion of lead particles
3	• Keep eating area clean	Minimizes cross-contamination to dining tables, food, drink, and personnel
4	• Wash hands before eating	Minimizes cross-contamination from hands to food
5	• Shower daily at the end of the workday, before going home	Minimizes chance of taking lead particles home or into the surrounding environment
6	• Change workwear—Change out of work clothes before going home	Use of separate work clothes will keep street clothes from tracking lead particles outside the SLAB site
7	• Change and launder workwear daily	All workwear should be left at the SLAB recycling facility and should be laundered on site to minimize tracking of any particles off site; water from laundry should be collected and treated
8	• Check and clean respirators daily	Remove any buildup of particles or lead particles in the respirators and ensure maximum worker protection
9	• Wear respirators	Minimizes lead exposure from processing operations
10	• Wear work clothes	Minimizes risk of carrying lead contamination outside of the facility
11	• Install mechanical controls to reduce employee exposure to lead dust in air	Reduces the required levels of PPE needed to protect employees from exposure to lead dust in the air
12	• Keep homes, vehicles, and personal property clean	If any contamination is introduced into personal property, it will be reduced through cleaning

Source: Wilson, B. 2009. Recycling used lead acid batteries: A model lifecycle approach. Presented at the Asian Battery Conference, 31 August–1 September 2009. <www.ilmc.org/Presentations/ABC/Recycling%20Used%20Lead%20Acid%20Batteries%3B%20A%20Model%20Life%20Cycle%20Approach.pdf>.

- Food and beverages should only be consumed in lunchrooms, break rooms, or other designated areas. Cosmetics should only be applied in change rooms, lunchrooms, break rooms, or showers. Tobacco products should only be consumed in designated areas, typically outdoors.
- All protective clothing should be removed at the end of a work shift in change rooms provided for that purpose (Figure 31).[133]
- Change rooms should be equipped with separate storage facilities for protective work clothing and equipment and for street clothes.
- Employees exposed to lead should shower at the end of the work shift.
- Shower facilities should be provided (Figure 32).
- Employees should not leave the workplace wearing any clothing or equipment worn during the work shift.
- Lunchroom facilities should be provided for employees (Figure 33).
- Lunchroom facilities should have a temperature-controlled, positive-pressure, filtered air supply.
- Employees should wash their hands and face before eating, drinking, smoking or applying cosmetics (Figure 34).
- Employees should not enter lunchroom facilities with protective work clothing or equipment unless surface lead dust has been removed by vacuuming or another cleaning method.
- Clean and dry protective work clothing should be provided daily or weekly, depending on exposure levels.[134]
- Personal protective equipment (PPE) should be repaired or replaced as needed to maintain its safety and effectiveness.[135]
- Contaminated protective clothing, which is to be cleaned, laundered or disposed of, should be placed in a closed, labeled container in the changing area.[136]
- Cleaning, laundering, or disposal of protective clothing and equipment should be provided.[137] Persons who clean or launder protective clothing or equipment should be informed in writing of the potentially harmful effects of exposure to lead.[138]
- Removal of lead from protective clothing or equipment by blowing or shaking disperses lead into the air and should be avoided.[139] Figures 35 through 38 show the proper methods of removing lead particles from various pieces of protective clothing.

132. United States Department of Labor. n.d.(a).
133. *Idem.*
134. United States Department of Labor n.d.(c).
135. *Idem.*
136. North Carolina Department of Transportation 1996.
137. *Idem.*
138. *Idem.*
139. *Idem.*

Figure 31
Clothes Changing Room

Source: United States Department of Labor. n.d.(a). Occupational Safety & Health Administration (OSHA) Lead requirements: Hygiene facilities. <www.osha.gov/SLTC/etools/battery_manufacturing/requirements/hygiene.html#clean_areas>.

Figure 32
Locker Room and Showers

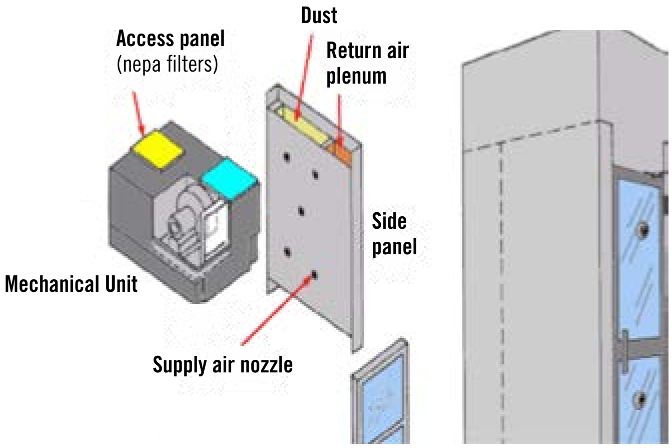
Source: Sim, M. 2013. Battery recycling done correctly. *Pollution Blog*. <www.blacksmithinstitute.org/blog/wp-content/uploads/2013/09/clean-locker-room.jpg>.

Figure 33
Employee Lunchroom

Figure 34
Hand-wash Station

Source: United States Department of Labor. N.d.(a). Occupational Safety & Health Administration (OSHA) Lead requirements: Hygiene. facilities. <www.osha.gov/SLTC/etools/battery_manufacturing/requirements/hygiene.html#clean_areas>.

Figure 35
Components of a Clothes-cleaning Air Shower



Source: United States Department of Labor. n.d.(a). Occupational Safety & Health Administration (OSHA) Lead requirements: Hygiene facilities. <www.osha.gov/SLTC/etools/battery_manufacturing/diagrams/hygiene_shower.gif>.

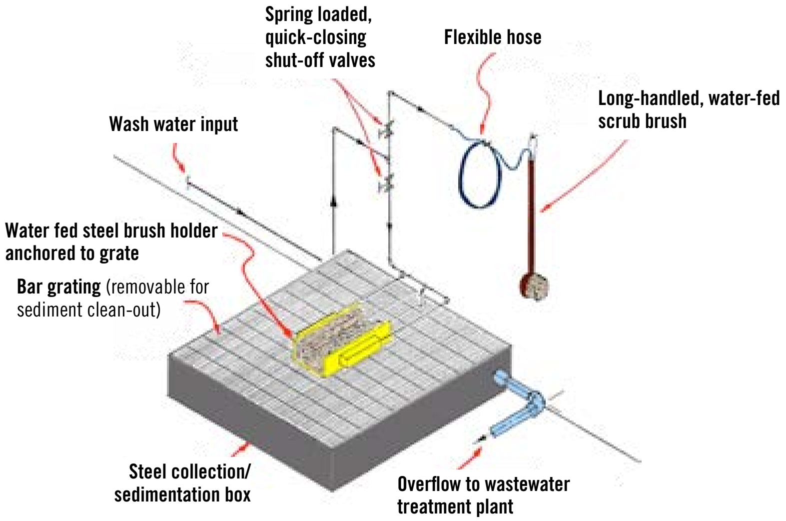
Figure 36

Vacuum to Remove Lead Particles from Protective Clothing

Source: United States Department of Labor. n.d.(a). Occupational Safety & Health Administration (OSHA) Lead requirements: Protective clothing and equipment. <www.osha.gov/SLTC/etools/battery_manufacturing/requirements/ppe.html>.

Figure 37

Diagram of a Boot-wash Station to Remove Lead Particles



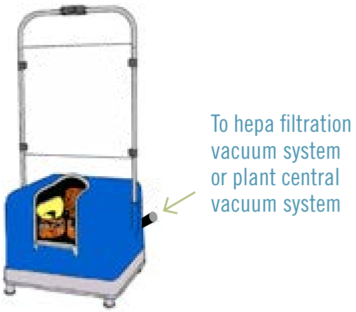
Source: United States Department of Labor. n.d.(a). Occupational Safety & Health Administration (OSHA) Lead requirements: Protective clothing and equipment. <www.osha.gov/SLTC/etools/battery_manufacturing/popup/general_boot-wash.html>.

Figure 38

Diagram of a Shoe-cleaning Machine for Removal of Lead Particles

OPERATING INSTRUCTIONS

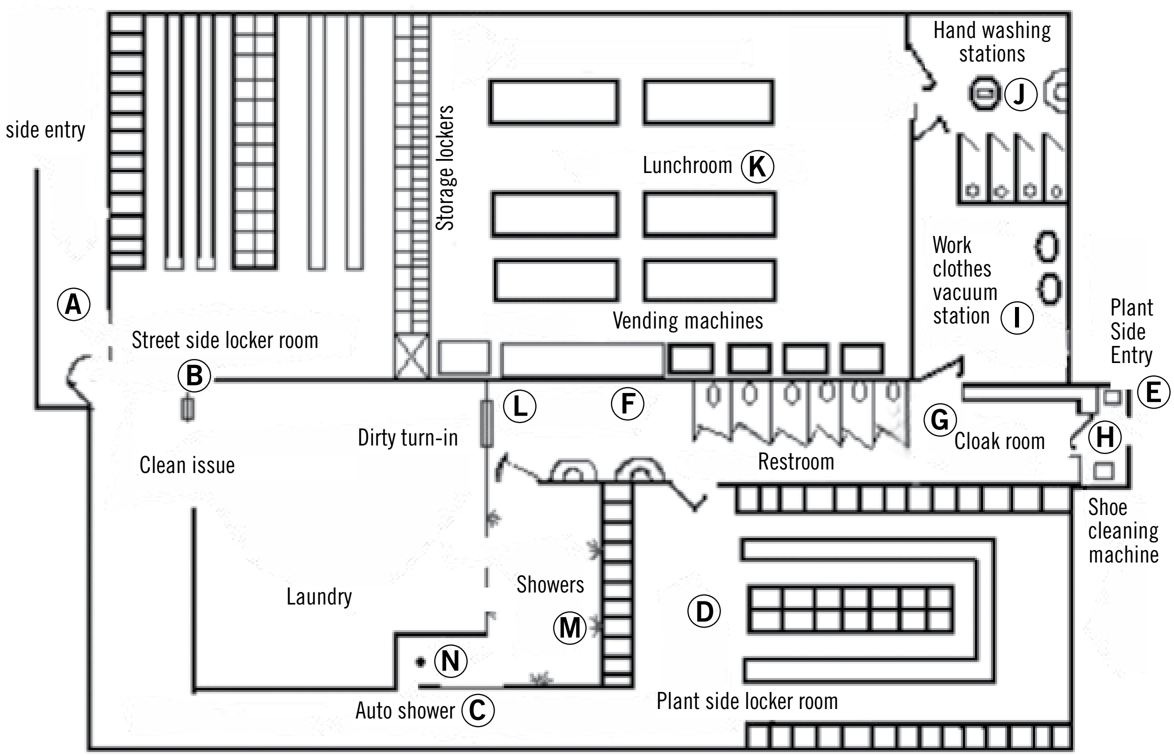
1. Stand as close to machine as possible
2. Hold handle, press switch and hold
3. Insert shoe as far as possible, withdraw and repeat 2 or 3 times
4. After completing 2nd shoe, release switch



Source: United States Department of Labor. n.d.(a). Occupational Safety & Health Administration (OSHA) Lead requirements: Hygiene facilities. <www.osha.gov/SLTC/etools/battery_manufacturing/popup/hygiene_shoe-clean.html>.

Figure 39

Components of a Two-stage Hygiene Facility



Source: United States Department of Labor. n.d.(b). Occupational Safety & Health Administration (OSHA) Lead requirements: Hygiene facilities. <www.osha.gov/SLTC/etools/leadsmelter/popups/hygienefac_popup.html>.

Figure 39 illustrates a two-stage hygiene facility. It includes the following features (described with reference to the Figure):[140]

The facility can be entered from the street at only one point **(A)**.

- Street clothes are removed and clean work clothes, hardhat, and respirator are issued and donned in the street side locker room **(B)**.
- The employee passes through a one-way turnstile in order to get to the plant-side locker room **(C)**.
- The employee dons work boots and other safety gear in the plant-side locker room where they are stored **(D)**.
- There is only one entry to the plant **(E)**.
- The restroom just inside the cloakroom is readily accessible during working hours **(F)**.
- The cloakroom provides a place to store coats, hardhats, gloves and respirators during break periods **(G)**.
- During lunch break the employee first cleans his/her boots at the shoe-cleaning machines **(H)**, leaves coat and equipment in the cloak room **(G)**, vacuums off his/her clothes at the vacuum stations **(I)**, proceeds to the hand-washing station where he/she thoroughly washes his/her hands **(J)**, and finally enters the lunchroom **(K)**.
- At the end of the shift the procedure is as follows: the employee cleans shoes **(H)**, removes contaminated clothing in the plant-side locker room **(D)**, stores boots and other PPE in plant-side lockers, turns in dirty work clothes, hardhat and respirator to laundry **(L)**, and proceeds to the showers. **(M)** He/she then must pass through an automatic shower **(N)** to return to the street-side locker room **(B)**, where he/she dresses and leaves the faculty **(A)**.

140. United States Department of Labor n.d.(a).

Several facilities throughout North America have already implemented a number of the work practices described in this section. One company, for example, requires workers to change their street clothes once they arrive at the facility, and wearing PPE is mandatory whenever they are in the plant. All work clothes are washed daily on site. To prevent workers from carrying lead back to their families at home, workers are also required to take a shower before changing into their street clothes.

6.3.1 Personal Protective Equipment

The proper use of PPE is essential for protecting workers at SLAB recycling facilities from exposure to lead, acid and other environmental contaminants or hazardous substances (see Figure 40 for an illustration).

The type of PPE required will vary for different locations within the recycling facility, as the risks and exposures vary. Each area of the SLAB recycling facility should have clear notices and signs posted outlining what PPE a worker should use while in that given area, and all workers should be trained on how to use each piece of PPE.

Depending on the jurisdiction's requirements, the minimum requirements for PPE may include:

- respirators (half-mask, full-face or air-powered, with combination filters for particulate and for organics such as sulfuric acid),
- hard hats,
- nitrile and chemical gloves,
- standard aprons,
- chemical-resistant aprons (more specific and heavy-duty than standard apron),
- safety glasses or vented goggles,
- hearing protection,
- thermal protective gear (furnacing operations),
- chemical-resistant steel-toed safety boots (these are good as they offer better protection in wet areas),

Figure 40

Example of Personal Protective Equipment (PPE)

Source: Sim, M. 2013. Battery recycling done correctly. *Pollution Blog*. <www.blacksmithinstitute.org/blog/wp-content/uploads/2013/09/man-and-lead.jpg>.

- Tyvek coveralls with chemical coating (alternative to cloth coveralls), or similar full-body work clothing,
- face shields (can attach to the hard hat), and
- disposable shoe coverlets.

6.4 Environmental and Health Monitoring at SLAB Recycling Facilities

The cardinal rule for any management system is that "you cannot manage what you do not measure." Ongoing monitoring, measurement and feedback provide useful data that can lead to continuous improvement and ESM. Examples of key monitoring programs to have in place at a SLAB recycling facility include:

- air quality monitoring,
- surface sampling,
- noise exposure monitoring,
- medical monitoring (i.e., worker health), and
- water quality monitoring.

Each of these is discussed separately in this section.

All testing should be done at certified and approved laboratories, in compliance with standards such as US EPA and Canadian test methods for measuring/sampling lead from point sources such as smokestacks.[141] In Mexico, testing should be carried out at laboratories endorsed by the appropriate authorities.

A process should be in place to continuously evaluate and re-evaluate any activities that may cause potential exposure, in order to reduce risk to human life and the surrounding environment.

6.4.1 Air Quality Monitoring at Secondary Lead Recycling Facilities

SLAB recycling facilities should monitor air quality for the following parameters:

- lead particulate,
- sulfuric acid vapors, and
- cadmium particulate (optional).

A typical approach used for air quality monitoring at secondary lead recycling facilities is described below. This approach is based on a combination of US agencies (Occupational Safety and Health Administration [OSHA] 29 CFR, Environmental Protection Agency [EPA] 40 CFR, and National Institute for Occupational Safety and Health [NIOSH]), as well as other sources.

141. EPA Method 12 tests for inorganic lead: <www.epa.gov/ttn/emc/promgate/m-12.pdf>. EPA Method 29 tests for lead particulates (amongst a number of other metals): <www.epa.gov/ttn/emc/promgate/m-29.pdf>. Tests for lead and other particulate metal emissions: <www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=95F47AF7-1>.

- Passive sampling should be conducted using air sampling pumps.
- Samples should be collected during non-operating or shutdown periods, to establish baseline data.
- Personal air sample should be collected for identified air contaminants:
  - by person, for an 8-hour time-weighted average (TWA),
  - by job task, for an 8-hour TWA.
- Area air sampling for lead and cadmium should be conducted:
  - at the source (at a specific task area),
  - at a 3 m (10 ft) radius from the emission source (consider both parallel and perpendicular directions, vertical/horizontal), and
  - at a 6 m (20 ft) radius from the emission source (consider both parallel and perpendicular directions, vertical/horizontal).
- Samples should be evaluated by a certified laboratory[142] for metals and particulate matter.
- Sampling should follow the following OSHA 29 CFR standards (or equivalent), as applicable:
  - 1910.120 Hazardous Waste Operations and Emergency Response,
  - 1910.1200 Hazard Communications,
  - 1910.1025 Lead Standard, and
  - 1910.1027 Cadmium Standards.
- OSHA 29 CFR 1910.134 Respirator Protection should be applied, as applicable.

Figures 41 to 43 provide examples of different monitoring pumps and air sampling cartridges that can be used for air quality monitoring at SLAB recycling facilities.

Figure 41

Personal or Area Air Sampling Pump

Source: SKC Inc. 2014. Universal PCXR4 5 to 5000 ml/min. <www.skcinc.com/catalog/index.php?cPath=100000000_101000000_101000350>.

Figure 42

Complete Personal Air Sampling System

Source: SKC Inc. 2015. Gilian air sampling equipment from Sensidyne. <www.sensidyne.com/air-sampling-equipment/sampling-media-accessories/>

Figure 43

Lead in Air Sampling Kit

Source: SKC Inc. 2015. <www.skcinc.com/catalog/product_info.php?cPath=22&products_id=123>.

142. In Mexico, samples should be evaluated by laboratories endorsed by the appropriate authorities.

6.4.2 Water Quality Monitoring at Secondary Lead Recycling Facilities

Wastewater sampling should be carried out on a regular basis to measure the concentrations of the following parameters in effluents from the secondary lead processing operation:

- metals—silver (Ag), arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), and selenium (Se),
- pH levels,
- biochemical oxygen demand (BOD),
- chemical oxygen demand (COD),
- total dissolved solids (TDS), and
- total suspended solids (TSS).

Water sampling at secondary lead processing facilities is carried out to ensure that the wastewater treatment system is working efficiently to remove lead from the wastewater being discharged so as to lower lead levels to those acceptable to local, state/provincial, and/or national/federal regulators. The sampling approach includes the following procedures:

- Sample water sources both inside and surrounding operations to evaluate for possible contaminants.
- Samples should be collected during non-operating or shutdown periods, to establish baseline data.
- Evaluations should be made on both incoming clean water supplied to process and sanitary facilities and any discharge water from process and sanitary discharge points.
- Collect a grab sample at different times of the day to evaluate all possible conditions.
- Samples should be tested by a certified laboratory for metals concentrations, particularly lead, as well as other standard water quality parameters (pH, turbidity, COD) and other parameters set by local or other regulators.[143]
- Sample results are evaluated based on set parameters identified in local, regional, and/or national/federal operating permits granted to the operating facility.

6.4.3 Surface Sampling at Secondary Lead Recycling Facilities

In order to establish the presence of contaminants of concern, surface sampling at SLAB recycling facilities should measure the following parameters:

- lead, and
- cadmium (optional; should not be present, but it will help to determine if employees—especially smokers—are following through with proper hygiene procedures).

The sampling approach should follow that set forth by NIOSH 9100[144] and include the following procedures:

- Surfaces to be sampled must include any points that should be clean and free of contamination, such as offices, desks, restrooms, break rooms, clean rooms, and meeting spaces.
- Samples should be collected during non-operating or shutdown periods, to establish baseline data.
- Swipe samples of identified surfaces should be collected at various intervals and locations during the day, to provide the best evaluation of surface contamination.
- Samples should be evaluated by a certified laboratory for metal concentrations, following the EPA SW-846 Test Method Manual (or equivalent).
- Instant or "spot" sampling can be conducted at any time, to evaluate the presence of an identified contaminant such as lead. This type of sampling will identify the presence but not the amount of contamination present at the sample point.

Examples of materials used for surface sampling are shown in Figures 44 and 45.

6.4.4 Noise Measurement

The first step in measuring workplace noise is to determine whether or not there is a noise problem. In order to establish a baseline noise level, general workforce exposure measurements (area sampling) should be collected during non-operating or shutdown periods. Several measurements should be taken at different locations within a workplace to estimate employee exposures to noise.[145] Once it is determined that noise is a problem, personal employee samples should be collected to determine individual exposure based on task. Measuring noise levels and workers' noise exposures should be conducted following a procedure such as OSHA 29 CFR 1910.95 or the standard that applies in the facility's jurisdiction.

Two instruments are available to measure noise exposures: the sound level meter and the dosimeter.

A sound level meter determines a person's instantaneous exposure to noise by detecting the small air pressure

143. In Mexico, testing of samples should be conducted by laboratories endorsed by the appropriate authorities.
144. Centers for Disease Control and Prevention 1994.
145. Cohen, J.M., and R.D. Peterson 1995.

Figure 44

Example of a Wipe Used for Surface Sampling

Source: SKC Inc. 2014. Ghost Wipes for lead and other metals. <www.skcinc.com/catalog/index.php?cPath=600000000_601000000_601000100>.

Figure 45

Wipe Sampling Kit for Sampling of Lead on Skin and Surfaces

Source: SKC Inc. 2014. Full Disclosure detects lead on skin & surfaces. <www.skcinc.com/catalog/index.php?cPath=600000000_601000000_601000050>.

variations associated with sound and changing them into electrical signals. These signals are processed by the electronic circuitry of the meter, and then the readout displays the sound level in decibels.[146]

A dosimeter is like a sound level meter that stores noise level measurements over time, providing an average noise exposure reading for a given period, such as an 8-hour workday. Examples of noise dosimeters are presented in Figures 46 and 47 (Note: Reproducing product name brands in the photographs in this document in no way constitutes endorsement of those products by the CEC or by any of the three governments).

6.4.5 Medical Monitoring

Medical/biological monitoring of employees at secondary lead recycling facilities should include the following:

- full blood analysis annually for the following parameters (more frequently if parameters of concern are identified):
  - complete blood count,
  - basic metabolic blood panel (Chem 7),
  - urinalysis,
  - blood for lead cadmium and mercury, and
  - urine for cadmium and mercury,
- partial blood draw biannually to test for lead and cadmium (optional),
- respiratory physical,
- audiograms, and
- chest X-rays.

Cadmium test results help assessors to understand the additional burden as a result of smoking, and to document baseline numbers for smokers, since their bodies will absorb lead faster and release lead more slowly than a non-smoker.

Figure 46

Dosimeter Used for Noise Testing

Source: 3M. 2015. 3M™ Edge™ Dosimeters. <http://solutions.3m.com/wps/portal/3M/en_EU/PPE_SafetySolutions_EU/Safety/Product_Catalogue/~/3M-Edge-Dosimeters?N=5158380+3294411297+3294857473&rt=rud>.

Figure 47

Dosimeter Used for Noise Testing

Source: Casella CEL Inc. 2014. dBadge Micro Noise Dosimeter CEL-350. <www.casellausa.com/store/product.cfm?pID=7C504B4D4D197450>.

146. Canadian Centre for Occupational Health and Safety 2015b.

Medical monitoring programs are necessary in order to monitor the health of employees and to prevent unnecessary exposure and long-term adverse health effects related to the work environment. Monitoring should be conducted and managed by licensed health care professionals.

Testing may include biological and physical evaluations and should be conducted at various frequencies, depending upon identified concerns.

6.5 Emergency Plans

All facilities should develop and have on site an emergency preparedness plan that outlines procedures to be implemented in case of emergencies such as fires, chemical spills, explosions, earthquakes, and/or unplanned releases of hazardous products. All employees should be aware of what needs to be done in case of an emergency or when specific alarms are activated. Employees need to be aware of and familiar with evacuation plans and meeting points where employees congregate, through periodic emergency procedure drills. One employee should always be on call in case of emergency, with the responsibility to coordinate the response to the emergency.

To develop the emergency plan, facility owners and operators should consult with local police and fire departments, hospitals, federal/national/state/provincial staff, local emergency response teams who coordinate local resources to address emergencies, as well as local municipal governments, and contractors who would be on call to help with addressing the emergency. An implementation checklist for monitoring and environmental protection at SLAB recycling facilities is shown in Table 18.

At a minimum, the emergency plan should include the following:

- ✓ **Describe the action to be taken to minimize hazards** to human health firstly, but also to protect the environment (air, land and water) from any unplanned releases of hazardous wastes or other materials that could pose harm to the environment.
- ✓ **List the names and contact numbers for all personnel qualified to act as emergency coordinators**, with the primary emergency response coordinator identified, as well as a number of other personnel who are trained to act as emergency coordinators and should be contacted if the primary emergency coordinator is not available. It is essential that the emergency contact list be always up to date.
- ✓ **Describe all emergency equipment on site** (e.g., fire-extinguishing systems, spill control kits, communications and alarm systems, and decontamination equipment) and identify their location within the facility.

Table 18. **Implementation Checklist for Monitoring and Environmental Protection at SLAB Recycling Facilities**

Implementation Area	Key ESM Activity	Actions and Considerations	For details, see the listed section above
Control measures to protect workers' health and safety	Follow required occupational health standards	☐ Know and follow required occupational health and safety laws for jurisdiction, especially pertaining to lead permissible exposure levels and blood lead levels ☐ Conduct risk assessments to determine hazards and to plan and implement controls or improvements to address risks ☐ Implement proper work practices	§6.1 §6.2 §6.3
Personal Protective Equipment	Protect workers in all possible exposures, using correct controls based on risk assessments and regulatory requirements	☐ Respirators: half-mask, full-face or air-powered, with combination filters ☐ Hard hats ☐ Nitrile and chemical gloves ☐ Aprons or chemical aprons (more specific and heavy duty than standard aprons) ☐ Safety glasses or vented goggles ☐ Hearing protection ☐ Thermal protective gear (at furnace or hot works) ☐ Chemical steel-toed safety boots ☐ Tyvek coveralls with chemical coating or similar full-body work clothing ☐ Face shields (can attach to the hard hat) ☐ Disposable shoe coverlets	§6.3

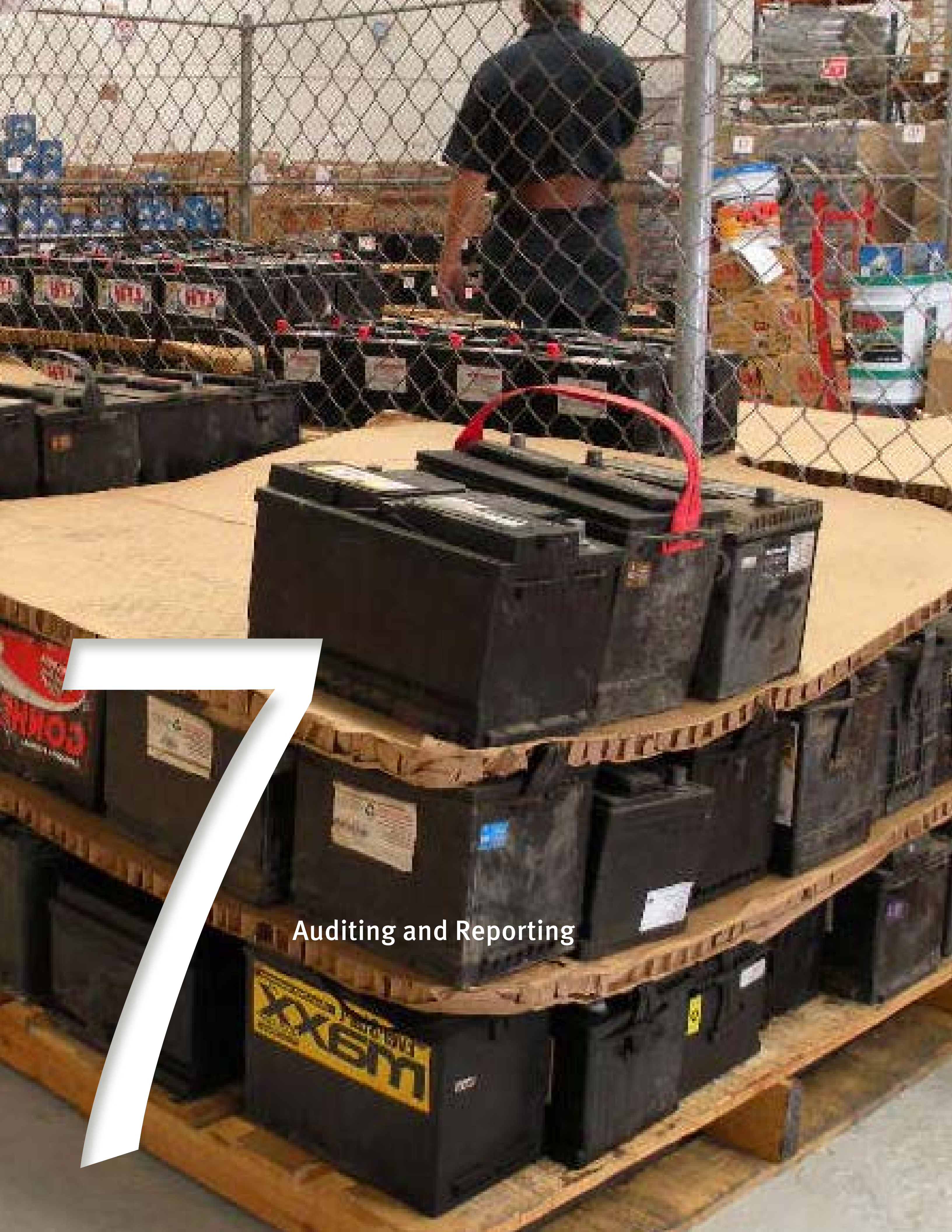
Monitoring	Personal exposure monitoring	☐ Design and implement comprehensive air quality monitoring system, including:
		  ☐ Passive sampling
		  ☐ Personal and area air samples
		  ☐ Certified laboratory analysis of samples
		  ☐ Respirator as applicable per regulatory requirements
			§6.4.1

	Surface sampling and testing	☐ Sample work and adjacent surfaces at facility for lead and cadmium, following established and proven sampling protocols to collect swipes ☐ Certified laboratory analysis of samples	§6.4.3

	Noise measurement	☐ Measure sounds in and around facility regularly to estimate employee noise exposure—sample:
		  ☐ During shutdown, to establish baseline noise
		  ☐ Several areas, to establish background noise
		  ☐ Employee task areas, to determine individual exposure
			§6.4.3

	Medical monitoring	☐ Regular physicals of employees for lead and other chemical exposure, including blood and urine analysis, respiratory and audio testing, and chest x-rays.	§6.4.5
	Water quality	☐ Design and implement comprehensive water quality monitoring system, including regular sampling for metals, biochemical and chemical oxygen demand, and total dissolved and suspended solids ☐ Follow established and proven sampling protocols ☐ Certified laboratory analysis of samples	§6.4.2

Emergency Plans	Develop an emergency preparedness plan	☐ Develop and implement an emergency preparedness plan that outlines procedures to be implemented in case of emergencies. The plan should:
		  ☐ Describe the action(s) to be taken to minimize hazards to human health and the environment from any unplanned releases of hazardous wastes or other materials
		  ☐ List key contact names and numbers for all personnel qualified to act as emergency coordinators, in case of emergencies
		  ☐ Describe all emergency equipment on site and its location
			§6.5



7 Auditing and Reporting

7 Auditing and Reporting

7.1 Auditing

Audits should be carried out on a periodic basis to confirm that facilities are measuring their performance in a way that is consistent with these technical guidelines. The International Standards Organization (ISO) has developed guidelines to help ensure that audit conclusions are reliable and accurate, and that enable auditors working independently from one another to reach similar conclusions in like circumstances. Among these standards are ISO 19011 and ISO 17021. All audits at SLAB recycling facilities should be conducted by a certified professional and should follow ISO 19011 and ISO 17021 Guidelines, or an equivalent standard.

ISO 19011 sets forth "guidance on auditing management systems, including the principles of auditing, managing an audit program, and conducting management system audits, as well as guidance on the evaluation of competence of individuals involved in the audit process, including the person managing the audit program, auditors, and audit teams."[147]

Supplementing ISO 19011 is ISO 17021, which "contains principles and requirements for the competence, consistency and impartiality of the audit and certification of management systems of all types (e.g., quality management systems or environmental management systems) and for bodies providing these activities."[148]

7.2 Reporting

Facilities that receive and manage SLABs should implement and maintain a tracking system for controlling, weighing or counting, and documenting total inbound and outbound materials, wastes, and equipment and components sent for recycling. Tracking systems should be implemented at each facility, including for materials in off-site storage or locations.

For reporting purposes and to demonstrate compliance with regulatory requirements, SLAB recycling facilities should maintain records of operational activities on a monthly basis. All records should be readily accessible and available for both internal staff and external third-party review during the lifespan of the facility. Records may include, but are not limited to:

- identification of generators and transporters of the SLABs;
- information on key performance indicators, such as the facility's recycling efficiency rate, recovery rate, and residual rate (definitions vary by jurisdiction)—for some facilities these may be considered proprietary and may not be available for review;
- description of how waste materials were processed;
- the origin and quantity of material received (mass, unit and/or volume) by material or item type;
- the quantity (mass, unit and/or volume) of material stored, awaiting processing, recycled, re-used and/or refurbished, and shipped downstream;
- the quantity (mass, unit and/or volume) and type of residual material sent to disposal and the disposal method;
- the quantity (mass, unit and/or volume) and types of materials sold/redistributed;
- a description of any complaints received; and
- quarterly facility reviews of documentation, as well as inbound and residual material flows.

There are numerous recognized benefits that come from adopting and implementing ESM practices, including:

- increased business opportunities for companies—clients now frequently demand that processors of end-of-life components associated with their products use ESM practices, therefore ESM can be a marketing advantage for all companies throughout the supply chain;
- increased recovery of materials of high economic value, such as lead;
- enhanced operational efficiency by implementing new systems and procedures that focus on reducing waste, reusing, and recycling;
- improved worker health and safety, as well as protection of the local community and the environment; and
- assurance of meeting regulatory and legal requirements.

147. International Standards Organzation 2011b.
148. International Standards Organization 2011a.

Appendix: Existing Spent Lead-acid Battery Recycling Facilities in North America

Facilities Processing SLABs in Canada

Facility Name	Location	Description
Metalex Products Ltd.	Richmond, British Columbia	All other miscellaneous manufacturing
Teck Trail Operations	Trail, British Columbia	Non-ferrous metal (except aluminum) smelting and refining
K.C. Recycling Ltd.	Trail, British Columbia	Collector and battery breaker
Tonolli	Mississauga, Ontario	Non-ferrous metal rolling, drawing, extruding and alloying
Newalta	Ste-Catherine, Quebec	Non-ferrous metal foundries
Glencore – Brunswick Smelter	Belledune, New Brunswick	Non-ferrous metal (except aluminum) smelting and refining

Facilities Processing SLABs in Mexico

Facility Name	Location	Description
Proveedora de Metales y Similares, S.A. de C.V.	Aguascalientes, Aguascalientes	Waste collection
Óxidos y Pigmentos Mexicanos, S.A. de C.V.	Tijuana, Baja California	SLABs Recycling, smelting and refining
Martha Alicia Boites Jiménez	León, Guanajuato	Waste collection, drawing and extruding
Funofec, S.A.	Tizayuca, Hidalgo	Waste collection
Dian Procesos Metalúrgicos, S.A. de C.V.	Tlajomulco, Jalisco	Waste collection, drawing and extruding
Sion Acumuladores, S.A. de C.V.	El Salto, Jalisco	Waste collection, drawing and extruding
Industrial Mondelo, S. de R.L. de C.V.	Lerma, Estado de México	Waste collection, oxides, and lead sulfate, SLABs Recycling
Industrias Deutsch, S.A. de C.V.	Cuautitlán, Estado de México	Lead recycling, lead oxides
La Batería Verde, S.A de C.V.	Tezoyuca, Estado de México	SLABs Recycling
Eric Odranoel Bobadilla Quintero	Morelia, Michoacán	Waste collection, recycling
MG Recicles, S.A. de C.V.	Ecuandureo, Michoacán	Waste collection, drawing and extruding
Corporación Pipsa, S.A. de C.V.	García, Nuevo León	Waste collection
Eléctrica Automotriz Omega, S.A. de C.V.	Doctor González, Nuevo León,	Waste collection, lead smelting
Enertec Exports (JCI), S. de R.L. de C.V. (planta Ciénega de Flores)	Ciénega de Flores, Nuevo León	SLABs Recycling
Enertec Exports (JCI), S. de R.L. de C.V. (planta García)	García, Nuevo León	Lead smelting and refining
Recicladora Industrial de Acumuladores, S.A. de C.V.	Santa Catarina, Nuevo León	Waste collection, Lead smelting

Facilities Processing SLABs in Mexico (continued)

Facility Name	Location	Description
Reciclajes y Destilados Monterrey, S.A. de C.V.	García, Nuevo León	Waste collection
Recmat de México, S. de R.L. de C.V.	García, Nuevo León	Lead batteries
Productos Metalúrgicos Poblanos, S.A. de C.V.	Huejotzingo, Puebla	Waste collection
Fundametz México, S.A. de C.V.	San Luis Potosí, SLP	Waste collection
Omega Recy, S.A. de C.V. (formerly Omega Solder México, S.A. de C.V.)	San Luis Potosí, SLP	Waste collection, drawing and extruding
Versisa, S.A. de C.V.	San Luis Potosí, SLP	SLABs, Waste Collection
Fundidora VH, S.A. de C.V. (formerly Hornos de Fundición, S.A. de C.V.)	Valle Hermoso, Tamaulipas	SLABs, Waste collection
M3 Resources México, S. de R.L. de C.V.	Reynosa, Tamaulipas	Non-ferrous metal foundries
Metalurgic Xicohténcatl, S. de R.L. de C.V.	Tlaxco, Tlaxcala	SLABs, battery plates, oxides, and lead sulfate

Facilities Processing SLABs in the United States

Facility Name	Location	Description
The Battery Recycling Company	Arecibo, Puerto Rico	Non-ferrous metal rolling, drawing, extruding and alloying
The Doe Run Company – Buick Resource Recycling Division	Boss, Missouri	Non-ferrous metal rolling, drawing, extruding and alloying
East Penn Manufacturing Co., Inc.	Lyon Station, Pennsylvania	Battery manufacturing and recycling
Exide Technologies, Inc.	Muncie, Indiana	Non-ferrous metal rolling, drawing, extruding and alloying
Exide Technologies, Inc.	Canon Hollow, Missouri	Non-ferrous metal rolling, drawing, extruding and alloying
Gopher Resource Corporation	Eagan, Minnesota	Non-ferrous metal rolling, drawing, extruding and alloying
Gopher Resource Corporation – Envirofocus Technologies	Tampa, Florida	Non-ferrous metal rolling, drawing, extruding and alloying
Johnson Controls, Inc.	Florence, South Carolina	Non-ferrous metal rolling, drawing, extruding and alloying
RSR Corporation, Quemetco	City of Industry, California	SLABs Recycling
RSR Corporation, Quemetco	Indianapolis, Indiana	Non-ferrous metal rolling, drawing, extruding and alloying
RSR Corporation, Revere	Middleton, New York	Non-ferrous metal rolling, drawing, extruding and alloying
Sanders Lead Company	Troy, Alabama	Non-ferrous metal rolling, drawing, extruding and alloying

Glossary

action level	A concentration for a specific substance—calculated as an eight (8)–hour time-weighted average—which initiates certain required activities such as exposure monitoring and medical surveillance.[149]
baghouse or fabric filter	Dry particulates are trapped by filters made of cloth, paper or similar material. The particles are shaken or blown from the filters into a collection hopper. Baghouses are used to control air pollutants from steel mills, foundries, and industrial furnaces.
bag leak detection system	An instrument that is capable of monitoring particulate matter (dust) loadings in the exhaust of a baghouse in order to detect bag failures.[150]
baseline data	Initial collection of data, which serves as a basis for comparison with the subsequently acquired data.[151]
battery breaking	Process in which lead-acid batteries are broken, crushed or disassembled and separated into components.[152]
buffering agent	A weak acid or base used to maintain the acidity (pH) of a solution near a chosen value after the addition of another acid or base. The function of a buffering agent is to prevent a rapid change in pH when acids or bases are added to the solution.
collection hopper	A large, pyramidal-shaped container used in industrial processes to hold particulate matter that has been collected from expelled air. Hoppers are usually installed in groups to allow for a greater collection quantity. They are employed in industrial processes that use air pollution control devices such as dust collectors, electrostatic precipitators, and baghouses or fabric filters. Most hoppers are made of steel.[153]
collection sump	A drain at the lowest point of the area where any runoff or spills will flow.
curbing	A stone or concrete edging to a storage area, street or path.
decommissioning	In the context of these guidelines, the formal process to remove a secondary lead smelter from active status to closed or inactive status.[154]
dosimeter	Noise dosimeters measure and store sound pressure levels and, by integrating these measurements over time, provide a cumulative noise-exposure reading for a given period of time, such as an 8-hour workday, usually to comply with Health and Safety regulations such as the Occupational Safety and Health (OSHA) 29 CFR 1910.95 Occupational Noise Exposure Standard.[155]
dross	Lead-contaminated materials that are formed during the fusion process.[156]
electrolyte	Any acidic, basic or salt solution capable of conducting current. In a lead-acid battery, the electrolyte is a dilute solution of sulfuric acid (H_2SO_4) and water (H_2O).[157]
ESM	Environmentally sound management—a scheme for ensuring that wastes and used and scrap materials are managed in a manner that will save natural resources, and protect human health and the environment against adverse effects that may result from such wastes and materials.[158]
filter cake	Formed by the substances that are retained on a filter. When the filter cake gets to be a certain thickness, it has to be removed from the filter.[159]
fluxing agent	A chemical used for cleaning, flowing, or purifying during the metal smelting process.[160]

149. United States Department of Labor n.d.(b).
150. United States Federal Register. Environmental Protection Agency, 40 CFR Part 63 – Subpart X. National Emissions Standards for Hazardous Air Pollutants from Secondary Lead Smelting – Final Rule.
151. Business Dictionary n.d.
152. United States Federal Register. Environmental Protection Agency, 40 CFR Part 63 – Subpart X. National Emissions Standards for Hazardous Air Pollutants from Secondary Lead Smelting – Final Rule.
153. Wikipedia contributors n.d.(e).
154. Wikipedia contributors n.d.(a).
155. https://en.wikipedia.org/wiki/Noise_dosimeter
156. Secretariat of the Basel Convention 2003.
157. C&D Technologies 2012.
158. Organization for Economic Cooperation and Development 2007.
159. Wikipedia contributors n.d.(c).
160. Wikipedia contributors n.d.(d).

fugitive emissions	Atmospheric discharges from raw materials and/or industrial processes that are released to the atmosphere without passing through any filtering device or control mechanism designed to reduce or eliminate the hazardous content or amount of the materials being produced prior to release to the environment.[161]
gravity separation	A process by which lead oxides and sulfates are separated from the other materials in a battery, based on their different densities.[162]
lead-acid battery	A rechargeable electro-chemical device used to store and produce electrical energy.[163]
lead refining	Removal of almost all copper, antimony, arsenic, and tin from crude lead bullion.[164]
neutralization	A chemical reaction in which an acid and a base react quantitatively with each other. In a reaction in water, neutralization results in there being no excess of hydrogen or hydroxide ions present in the solution. The pH of the neutralized solution depends on the acid strength of the reactants.[165]
nitrile gloves	A type of disposable glove made of synthetic rubber. Nitrile gloves are more puncture-resistant than many other types of rubber gloves and offer superior resistance to many types of chemicals.[166]
NO_x	A generic term for the mono-nitrogen oxides NO and NO_2 (nitric oxide and nitrogen dioxide). They are produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. NO_x gases react to form smog and acid rain.[167]
pallet	A flat transport structure that supports goods in a stable fashion while being lifted by a forklift.[168]
permitted exposure level	Regulatory limits on the amount or concentration of a substance in the air. PELs are based on an 8-hour time-weighted average (TWA) exposure.[169]
personal protective equipment	Protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury. The hazards addressed by protective equipment include physical, electrical, heat, chemicals, biohazards, and airborne particulate matter.[170]
point source	A single identifiable source of air, water, thermal, noise or light pollution. Point sources can be approximated as a mathematical point, to simplify analysis in pollution modeling.[171]
pyrometallurgical refining	Recovery of metal through thermal processes such as smelting.[172]
reagent chemical	Chemicals that are added to a system in order to bring about a chemical reaction.[173]
screening	Part of the battery breaking process, whereby small particles or fines are separated from electrode paste, which contains lead.[174]
SLAB	Spent lead-acid battery; a used lead-acid battery that cannot be adequately recharged to fulfill a useful purpose.[175]
slag	A byproduct of the smelting process; generally used to remove waste in metal smelting.[176]
smelting	The chemical reduction of lead compounds to elemental lead or lead alloys through processing in high-temperature (greater than 980^{o} Celsius) furnaces, including, but not limited to, blast furnaces, reverberatory furnaces, rotary furnaces, and electric furnaces.[177]

161. Secretariat of the Basel Convention 2003.
162. *Idem*
163. C&D Technologies 2012.
164. Secretariat of the Basel Convention 2003.
165. Wikipedia contributors n.d.(f).
166. Xintex Group n.d.
167. Wikipedia contributors n.d.(g).
168. Wikipedia contributors n.d.(h).
169. United States Department of Labor n.d.(c).
170. Wikipedia contributors n.d.(i).
171.Wikipedia contributors n.d.(j).
172. Commission for Environmental Cooperation 2007.
173. Wikipedia contributors n.d.(k).
174. Secretariat of the Basel Convention 2003.
175. Commission for Environmental Cooperation 2007.
176. Wikipedia contributors n.d.(l).
177. United States Federal Register. 40 CFR Part 63 – Subpart X. National Emissions Standards for Hazardous Air Pollutants from Secondary Lead Smelting – Final Rule.

smelting furnace charging point	The physical opening through which raw materials are introduced into a blast furnace.[178]
smelting furnace tap	Molten lead and slag are removed from the smelting furnace through the tap. Some taps transfer lead directly into a holding kettle, which keeps the metal molten for refining, while others transfer it into molds or ladles.[179]
stack emissions	Atmospheric discharges from raw materials and/or industrial processes that are released into the atmosphere after passing through a filtering device or control mechanism designed to reduce or eliminate the hazardous content or amount of the materials being produced prior to release into the environment.[180]
stretch wrap	Transparent plastic film used as packaging to enclose an article.
tail pulley	A pulley at the tail of the belt conveyor opposite the normal discharge end.[181]
terminal posts	Positive and negative terminals are lead posts that extend outside the plastic case of the battery, and are where the electric device is connected.[182]
tolling	A tolling agreement is an arrangement in which a smelter agrees to smelt the lead returned from battery manufacturers in exchange for a specified fee, or "toll."[183]
volatile organic compounds (VOCs)	Organic chemicals that have a high vapor pressure at ordinary room temperature. Their high vapor pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air.[184]
wet suppression	The spraying of water or mist to minimize dust particles blowing around the site.

178. *Idem*
179. United States Department of Labor n.d.(c).
180. Secretariat of the Basel Convention 2003.
181. McGraw-Hill 2003.
182. Secretariat of the Basel Convention 2003.
183. Commission for Environmental Cooperation 2013b.
184. Wikipedia contributors n.d.(m).

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