UNITED NATIONS

BC

UNEP/CHW.16/INF/12/Rev.1

Distr.: General
1 June 2023

English only

BASEL CONVENTION

**Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal**
**Sixteenth meeting**
Geneva, 1–12 May 2023
Agenda item 4 (b) (i)

**Matters related to the implementation of the Convention: scientific and technical matters: technical guidelines**

# Technical guidelines on the environmentally sound management of waste lead-acid batteries

## Note by the Secretariat

1. At its sixteenth meeting, the Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal considered the draft updated technical guidelines on the environmentally sound management of waste lead-acid batteries contained in document UNEP/CHW.16/INF/12.

2. The draft updated technical guidelines on the environmentally sound management of waste lead-acid batteries, which reflect the outcome of the sixteenth meeting of the Conference of the Parties and are taken note of in decision BC-16/6, on technical guidelines on the environmentally sound management of waste lead-acid batteries and on other waste batteries, are set out in the annex to the present note.

3. The present note, including its annex, has not been formally edited.

010623

# Annex

## Technical guidelines on the environmentally sound management of waste lead-acid batteries

# Contents

# Abbreviations and acronyms

| | |
|---|---|
| ABS | Acrylonitrile Butadiene Styrene |
| ANSI | American National Standards Institute |
| As | Arsenic |
| ASTM | American Society for Testing and Materials |
| BC | Basel Convention |
| BOD | Biological oxygen demand |
| BAT | Best available techniques |
| Bi | Bismuth |
| Ca | Calcium |
| $CaCO_3$ | Calcium carbonate |
| CAS | Chemical Abstracts Service |
| CEN | European Committee for Standardization |
| Cl | chlorine |
| CNS | Central nervous system |
| $CO_2$ | Carbon dioxide |
| COD | Chemical oxygen demand |
| Cu | Copper |
| DES | Deep Eutectic Solvents |
| EC | European Commission |
| ECHA | European Chemicals Agency |
| EDTA | Ethylenediamine tetra acetic acid |
| EIA | Environmental impact assessment |
| EMS | environmental management system |
| EN | European standard |
| EPR | extended producer responsibility |
| ESM | environmentally sound management |
| EU | European Union |
| $Fe_2O_3$ | Iron oxide |
| GHG | Greenhouse gas |
| $H_2O$ | Water |
| $H_2S$ | Hydrogen sulphide |
| $H_2SO_4$ | Sulphuric Acid |
| $HBF_4$ | |
| HSE | Health, safety & environment |
| IAEA | International Atomic Energy Agency |
| IATA | International Air Transport Association |
| ILO | International Labour Organization |
| IMO | International Maritime Organization |
| ISO | International Organization for Standardization |
| LAB | Lead-acid Battery |
| MEE | Ministry of Ecology and Environment (China) |
| MMSD | Mining, Minerals and Sustainable Development (IIED/WBCSD project) |
| MSW | municipal solid waste |
| HaOH | Sodium hydroxide |
| $N_2$ | Nitrogen |
| NEMA | National Electrical Manufacturers Association |
| NEWMOA | Northeast Waste Management Officials' Association |
| NGO | Non-governmental organisation |
| $NH_3$ | Ammonia |
| $NH_3PbCl_3$ | Ammonium lead chloride |
| $(NH_4)_2CO_3$ | Ammonium carbonate |
| $NH_4Cl$ | Ammonium chloride |
| NOx | nitrogen oxide |
| $O_2$ | Oxygen |
| OEWG | Open-ended Working Group (of the Basel Convention) |
| OECD | Organisation for Economic Co-operation and Development |
| OHSA | Occupational Health Safety Administration |
| Pb | Lead |
| PbB | Blood lead |
| PbO | Lead oxide |
| $PbO_2$ | Lead dioxide |
| $Pb(OH)_2$ | Lead hydroxide |
| $PbSO_4$ | Lead sulphate |
| PPE | Personal Protection Equipment |
| PVC | Poly Vinyl Chloride |
| QA/QC | Quality Assurance/Quality Control |

| | |
|---|---|
| QSP | Quick Start Programme |
| RPE | Respiratory Protection Equipment |
| SAICM | Strategic Approach to International Chemicals Management |
| Sb | Antimony |
| SETAC | Society of Environmental Toxicology and Chemistry |
| SCOEL | Scientific Committee on Occupational Exposure Lead |
| SLI | Starter, Lighting, Ignition |
| SME | Small Medium Enterprise |
| Sn | Tin |
| $SO_2$ | sulphur dioxide |
| SOP | standard operating procedure |
| S/S | stabilization and solidification |
| TCLP | toxicity characteristic leaching procedure |
| TOC | total organic carbon |
| UNDP | United Nations Development Programme |
| UNECE | United Nations Economic Commission for Europe |
| UNEP | United Nations Environment Programme |
| UNIDO | United Nations Industrial Development Organization |
| UNITAR | United Nations Institute for Training and Research |
| USEPA | Environmental Protection Agency (United States of America) |
| VLR | Valve regulated lead battery |
| WCO | World customs organisation |
| WLAB | waste lead-acid batteries |
| WHO | World Health Organization |
| Zn | Zinc |

# Units of measurement

| | |
|---|---|
| µg | microgram |
| mg | milligram |
| g | gram |
| kg | kilogram |
| mg/kg | milligram(s) per kilogram. Corresponds to parts per million (ppm) by mass. |
| L or l | litre |
| dL or dl | decilitre |
| $m^3$ | cubic meter |
| $cm^3$ | cubic centimeter |

# I. Introduction

## A. Scope

1. The present technical guidelines provide guidance on the environmentally sound management (ESM) of waste lead acid batteries (WLAB). This document supersedes the Basel Convention *Technical Guidelines for the Environmental Sound Management of Waste Lead-acid Batteries* of September 2003.

**Commented [BRS1]:** Co-lead countries and Small intersessional working group (SIWG) to consider adding text to acknowledge that Parties use the terms WLAB and ULAB interchangeably at the domestic level, and others see them in a different way.

2. The present guidelines cover waste lead-acid batteries categorised as hazardous wastes as defined under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

3. The WLAB covered by the present guidelines include the following:

**Commented [BRS2]:** UK: has a different way to define batteries.
Canada: duplication of content in paragraphs 3 and 19.
Sierre Leone: it would be important to state the reasons for this list, and why others are not listed.

(a) Automotive waste lead-acid batteries (start, lighting, ignition (SLI batteries);

(b) Generic/portable waste lead acid batteries (e.g., emergency lighting, alarm system batteries);

(c) Industrial waste lead-acid batteries (e.g., uninterrupted power supply batteries);

(d) Motive waste lead acid batteries (e.g., forklift truck, golf cart, wheelchair batteries, etc);

(e) Special waste lead acid batteries (e.g., scientific, medical, military applications);

(f) Stop/Start waste lead acid batteries.

4. The definition of wastes under the Basel Convention is described in paragraph 29 and waste lead-acid batteries are referenced in paragraphs 33-35.

## B. About lead-acid batteries

**Commented [BRS3]:** 1. SIWG to add information on the health effects and the risks to exposure to lead and sulfurique acid.

2. SIWG to see how to adapt this section and possibly to add references/sources to avoid that this section becomes quickly obsolete.

5. ~~Lead has been used for a variety of purposes for at least 8000 years and its history and uses is very well documented. There are numerous publications and historical accounts covering this[1]. Lead~~ Lead has one of the highest recycling rates of all commonly used materials and is the highest among metals and can be recycled indefinitely without reduction in quality. An average lead-acid battery can contain up to 10 kilograms of lead in the form of solid lead metal or lead-oxide paste. Consequently, each battery represents a valuable source of waste lead for recycling. The value of the worldwide lead-acid battery market is greater than US$ 54 billion (60% SLI, 18% stationary and 10% motive. Of this the industrial lead-acid battery market is valued at US$ 11 billion. The value of the lead-acid battery market is expected to be US$90 billion by 2030.

~~5.~~6. ~~Current total global annual primary and secondary production is estimated to be about 11.5 million tonnes.~~ Recycled waste lead-acid batteries (i.e., secondary lead) account~~s~~ for 57% of total annual lead production (11.5 million tonnes; ~~and this is predominately from waste lead acid batteries (~~74% in Europe, and 100% in US). Approximately 86% of lead produced is used for lead-acid batteries and the demand for these is expected to continue to grow through to 2030. The data would suggest that approximately 10 million tonnes of lead is used for annual battery production and of this about 6.5 million tonnes comes from recycling waste lead-acid batteries.

~~6. An average battery can contain up to 10 kilograms of lead in the form of solid lead metal or lead-oxide paste.~~

~~7. The value of the worldwide lead-acid battery market is greater than US$ 54 billion (60% SLI, 18% stationary and 10% motive. Of this the industrial lead-acid battery market is valued at US$ 11 billion. The value of the lead-acid battery market is expected to be US$90 billion by 2030[2].~~

~~8.~~7. Given the value of lead, its recyclability and demand from lead-acid battery production, waste lead-acid batteries are a valuable commodity for many people and businesses. Up to 99% of a waste lead-acid battery can be recovered. This makes the recycling ~~recovery~~ of batteries a viable and profitable business globally and represents opportunities for those engaged in ~~both~~ the environmentally sound management of WLAB~~formal and informal sectors~~.

~~[1] https://www.epa.gov/archive/epa/aboutepa/lead-poisoning-historical-perspective.html.~~

~~[2] https://indiashorts.com/latest-global-lead-acid-battery-market-size-share-worth-usd-90-billion-by-2030-at-a-5-cagr-custom-market-insights-analysis-outlook-leaders-report-trends-forecast-segmentation-growth-growth/96592/#:~:text=%E2%80%9CAccording%20to%20the%20latest%20research%20study%2C%20the%20demand,about%205%25during%20the%20forecast%20period%202022%20to%202030.%E2%80%9D.~~

8. The literature on the health and environmental effects of lead is extensive with many studies in workers and the general population and in particular children. Lead has been shown to have diverse biological impacts on neurological, renal, cardiovascular, haemopoietic, reproductive, genotoxic, and carcinogenic effects. In addition, studies also show the impact on flora and fauna demonstrating the need for and importance of environmentally sound management controls on lead during its manufacture, use and recycling to avoid adverse impacts.

9. Waste lead-acid battery electrolyte has the potential for adverse environmental and harmful health implications on the environment and human health for local communities if it is discharged without treatment or handled incorrectly. In addition, studies also show the impact on flora and fauna demonstrating the need for and importance of environmentally sound management controls on WLAB.

10. The handling, collection, transportation, and recycling/disposal of waste lead-acid batteries in an environmentally sound manner is essential to minimise the environmental and health impact of emissions of lead and other substances, such as battery electrolyte. The recycling of waste lead-acid batteries when properly applied and controlled can provides an economically viable and environmentally sound solution (energy and resource conservation) and is the optimally sound management of waste lead-acid batteries.

## C. Waste lLead-acid batteries, categories & waste streams

### 1. Overview

11. The Llead-acid batteryies areis essentially an electrochemical apparatus which provides electrical energy through the controlled use of chemical reactions. Some batteries use reversible chemical reactions and can be recharged, such as lead-acid batteries, while others known as primary batteries use non-reversible reactions and have just one useful lifetime.

12. Whatever application the typical waste lead-acid battery contains has been designed for it typically includes the following components:

(a) **Positive and negative terminals**: made of lead, and where the external electricity consumer devices are connected;

(b) **Connectors**: made of lead, that make electrical contact between plates of same polarity and make electrical contact between separated elements;

(c) **Cap and box:** originally ebonite, but now either polypropylene, a co-polymer or Acrylonitrile Butadiene Styrene (ABS);

(d) **Dilute sulphuric acid solution**: the battery electrolyte;

(e) **Element separators**: usually a part of the box and made of the same material, provides chemical and electrical isolation between electrical elements.

(f) **Plate separators**: made of permeable plastic or other porous materials, prevents physical contact between two contiguous plates but, at the same time, allows the free movement of ions in the electrolyte solution;

(g) **Battery plates:** comprise metallic lead structures (grids), covered by a lead dioxide-based paste, in the case of the negative plates, or by a porous metallic lead paste, in the case of the positive plates. The lead used in both the plates may also contain several other chemical elements such as antimony, arsenic, bismuth, cadmium, copper, calcium, silver, tin and in recent years, carbon. The plates manufacturing process also uses expander materials, such as barium sulphate, lampblack and lignin that are added to prevent the plate retraction during use. A standard battery has 13 to 15 plates.

13. In summary in a waste lead-acid battery contains lead metal and oxides (65% of the battery by weight), cell separators (polyester, polypropylene, fibrous glass matt – 7%), electrolyte (16%) and plastic or hard rubber casing (12% which). Most of these can all be recycled and reused.

### 2. Operation

**Commented [CV4]:** On behalf of the consultant: Is this section really needed - it was in the last one but I do not think it is relevant to this TG document.

SIWG to consider if this section or parts of it are to be kept in the document and how (e.g., move some text to other sections).

14. When the battery provides electric energy to an external device, such as a starter motor, several chemical reactions occur simultaneously. At the positive plates (cathode) a reductive reaction occurs when lead dioxide ($PbO_2$) is converted into lead sulphate ($PbSO_4$). On the negative plates (anode), an oxidative reaction occurs, and metallic lead is converted into lead sulphate.

15. While the battery discharges, for example, starting an automobile engine, the concentration of sulphuric acid slowly decreases from the electrolyte solution, since the sulphate ions become incorporated in the lead sulphate being formed at both electrodes. As this process continues, the active materials become depleted, and the speed of the reaction decreases until the battery is no longer able to provide electric energy. Most of the lead oxide and porous lead will then be in the form of lead sulphate.

16. When the battery is electrically recharged the reactions are reversed and the lead sulphate is electrochemically transformed into lead and lead oxide again.

17. The discharge-recharge process can be repeated several hundred times, but the lead oxide plates become increasingly contaminated by lead sulphate which eventually inhibits the chemical reactions. In addition, a sludge layer (55-60% $PbSO_4$; 20-25% PbO; 1-5% PbO; 1-5% metallic Pb) starts to accumulate at the bottom of the battery. Eventually the high level of contamination prevents recharging, and the battery is no longer useable.

## 3. Types and Applications

18. Lead-acid batteries have numerous applications and comprise different voltages, sizes, and weights, ranging from 2 kg no-break sealed batteries (e.g., security alarms) to industrial batteries which may weigh more than 2,000 kg (e.g., fork truck) or more.

19. Batteries are typically classified according to their use, as follows:

(a) Automobile – those batteries mainly used as the main energy source for starting, lighting, ignition (SLI batteries) in combustion engine vehicles such as cars, trucks, tractors, motorbikes, boats, planes, etc. Also used as auxiliary batteries in hybrid and full electric vehicles to power safety functions and other onboard electrics;

(b) Generic/portable - batteries used in, domestic alarm systems, emergency lights, etc.;

(c) Industrial - batteries for stationary applications such as telecommunications, electrical power stations, uninterrupted power supplies or no-breaks, load levelling, alarm and security systems, general industrial use and starting diesel motors;

(d) Motive - batteries used to transport loads or people: forklift trucks, golf carts, luggage transportation in airports, wheelchairs, electric cars, buses, etc.;

(e) Special - batteries used in specific scientific, medical, or military applications, and those that are integrated in electric-electronic circuits;

(f) Stop/start – batteries specifically designed to enable vehicles to stop using the engine when stationary and then restart when the accelerator is engaged. These batteries can save approximately 5% of fuel consumption and deliver equivalent reductions $CO_2$ emissions.

## 4. Battery Life

20. Battery life is the period during which it is capable of being recharged and retaining its charge. Once the battery cannot be recharged or retain sufficient charge, it reaches its end of life. The main cause of this is due to the sulphation process.

21. Under ideal conditions, an automobile battery can last up to six years or more, but several factors contribute to reduce its lifetime:

(a) An incomplete charging process or the battery remains too long without use or stands a long time between charges;

(b) Hot weather increases the sulphation process rate;

(c) Deep discharging processes, the deeper the discharge the less will be the lifetime of the battery. This is particularly the case with automobile batteries, but not so for energy storage batteries specifically designed for deep discharge;

(d) Low electrolyte level: air exposed plates become sulphated immediately. This only applied to flooded batteries and not to sealed maintenance free batteries or Valve Regulated Lead batteries (VLR).

22. When all these factors are considered, the battery life span ranges enormously from as little as 6 to 24 months to 6 to 10 years or more. To extend the battery life better battery labelling should address the correct procedures to prolong battery life, such as adding only deionised water, or usage tips about maintaining charge and so on. In addition, the adoption of new and improved recharging processes may increase the battery lifetime.

23. At the end of its life the battery, once it is ready to be discarded/recycled, it is classified as a hazardous waste under the Basel Convention and should be handled accordingly to prevent damage or threats to human health or the environment.

### 5. Lead-acid battery waste streams

24. Waste lead-acid~~During the recycling process the~~ batteries can be ~~are~~ broken down into several waste streams ~~for recycling/disposal~~, as follows:

(a) Metallic lead and lead alloys;

(b) Lead oxides;

(c) Lead sulphate;

(d) Battery electrolyte – dilute sulphuric acid;

(e) Plastic casing – polypropylene and ABS;

(f) Glass case material;

(g) Separators – glass and plastic;

(h) Furnace slags.

25. All of these are contaminated with lead and if they are improperly handled have the potential to have adverse effects on human health and/or the environment.

# II. Relevant provisions of the Basel Convention and international linkages

## A. Basel Convention

**Commented [BRS5]:** SIWG to consider revising this section to summarize details here presented.

### 1. General provisions

26. The Basel Convention, which entered into force on 5 May 1992, aims to protect human health and the environment against the adverse effects resulting from the generation, management, transboundary movements, and disposal of hazardous and other wastes. It does this via a set of provisions on the transboundary movement of wastes and their ESM. In particular, the Basel Convention stipulates that any transboundary movement (export, import or transit) of wastes is permissible only when the movement itself and the planned disposal of the hazardous or other wastes are environmentally sound. It states that hazardous wastes should be disposed of in the State where they are generated (i.e., the proximity principle). A set of provisions of the Basel Convention lays out Parties obligations to ensure the ESM of wastes. These are listed in paragraphs 31 to 34 below.

**Commented [BRS6]:** SIWG to consider revising this text.

27. Article 2 ("Definitions"), paragraph 1, of the Convention defines wastes as "substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law". Paragraph 4 of that article defines disposal as "any operation specified in Annex IV" to the Convention. Annex IV contains two categories of operations: those leading to the possibility of resource recovery, recycling, reclamation, direct reuse or alternative uses (R operations) and those not leading to this possibility (D operations). Paragraph 8 defines the ESM of hazardous wastes or other wastes as "taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes."

28. Article 4 ("General obligations"), paragraph 1, establishes the procedure by which Parties exercising their right to prohibit the import of hazardous wastes or other wastes for disposal shall inform the other Parties of their decision. Paragraph 1 (a) states: "Parties exercising their right to prohibit the import of hazardous or other wastes for disposal shall inform the other Parties of their decision pursuant to Article 13." Paragraph 1 (b) states: "Parties shall prohibit or shall not permit the export of hazardous or other wastes to the Parties which have prohibited the import of such wastes when notified pursuant to subparagraph (a) above."

29. Article 4, paragraphs 2 (a)-(e) and 2 (g), and paragraph 8, contain key provisions of the Basel Convention pertaining to environmentally sound management, transboundary movement, waste minimization and waste disposal practices aimed at mitigating adverse effects on human health and the environment:

Paragraphs 2 (a) – (e) and 2 (g): "Each Party shall take the appropriate measures to:

(a) Ensure that the generation of hazardous wastes and other wastes within it is reduced to a minimum, considering social, technological and economic aspects;

(b) Ensure the availability of adequate disposal facilities, for the environmentally sound management of hazardous wastes and other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal;

(c) Ensure that persons involved in the management of hazardous wastes or other wastes within it take such steps as are necessary to prevent pollution due to hazardous wastes and other wastes arising from such management and, if such pollution occurs, to minimize the consequences thereof for human health and the environment;

(d) Ensure that the transboundary movement of hazardous wastes and other wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes, and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement;

(e) Not allow the export of hazardous wastes or other wastes to a State or group of States belonging to an economic and/or political integration organization that are Parties, particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner, according to criteria to be decided on by the Parties at their first meeting;

(f) Prevent the import of hazardous wastes and other wastes if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner;

(g) Paragraph 8: "Each Party shall require that hazardous wastes or other wastes, to be exported, are managed in an environmentally sound manner in the State of import or elsewhere."

30. The Ban Amendment entered into force 5 December 2019, and it provides that Parties listed in Annex VII to the Convention (members of the European Union (EU), Organisation for Economic Cooperation and Development (OECD) and Liechtenstein) shall prohibit transboundary movements of hazardous wastes to States not listed in Annex VII of hazardous wastes which are destined for operations according to Annex IV-A and hazardous wastes under Article 1.1(a) which are destined to operations according to Annex IV-B[3].

**Commented [BRS7]:** SIWG to review the language in the paragraph in relation to the BAN Amendment, with a reference to Article 4A.

### 2. Provisions relating to waste lead-acid batteries

**Commented [BRS8]:** SIWG to consider including more specific entries of the Annexes of BC here.

31. Article 1 ("Scope of the Convention") defines the types of waste that are covered by the Basel Convention. Paragraph 1 (a) sets out a two-step process for determining whether a "waste" is a "hazardous waste" covered by the Convention; first, the waste belongs to one of the categories listed in Annex I to the Convention ("Categories of wastes to be controlled"), and second, it possesses at least one of the characteristics listed in Annex III to the Convention ("List of hazardous characteristics"). Lead falls into these categories and includes WLAB since they contain lead.

32. Annex I wastes containing lead are presumed to exhibit one or more of the hazardous characteristics listed in Annex III. These may include H6.1 "Poisonous (acute)", H11 "Toxic (delayed or chronic)", or H12 "Ecotoxic", unless, through "national tests", they can be shown not to exhibit such characteristics. National tests may be useful for identifying a particular hazardous characteristic listed in Annex III until such time as the hazardous characteristic is fully defined. Guidance papers[4] for some Annex III hazardous characteristics have been drafted under the Convention.

33. List A of Annex VIII describes wastes that are "characterized as hazardous under Article 1, paragraph 1 (a) of this Convention". This includes waste lead-acid batteries crushed or whole. Other specific lead wastes are also included.

## B. International linkages

### 1. World Customs Organisation

**Commented [CV9]:** On behalf of the consultant: Given that the WCO sets the codes for moving traded products such as WLAB this should be included as it specifically relates to the transboundary movements of WLAB

SIWG to assess if other elements of other instruments, protocols, etc should be added in this section.

SIWG to update the HSC codes that can be used here.

[3] For information on the status of individual Parties in relation to the amendment/s, please see the Status of Ratifications page on the Basel Convention website.

[4] The following papers are available at the Basel Convention website:
"Work on hazard characteristics - Approach to Basel Convention hazard characteristic H11: characterization of chronic or delayed toxicity"
"Interim guidelines on the hazardous characteristic H12-Ecotoxic"
http://basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx.

34. The Harmonized Commodity Description and Coding System (HS) of tariff nomenclature is an internationally standardized system of names and numbers for classifying traded products, which includes WLAB, has been developed and maintained by the World Customs Organization (WCO).

35. Under the WCO Harmonized System[5] (HS) of tariff nomenclature, waste lead-acid batteries are classified and coded as:

(a) HS 854810: for "spent primary cells, spent primary batteries and spent electric accumulators", that is, those WLAB that are neither usable as such because of breakage, cutting up, wear or other reasons and not capable of being recharged (Note 7 to Chapter 85);

(b) HS 850720: for WLAB other than automotive lead acid batteries, that is, solar, standby, motive, storage, industrial batteries that are at the end of life and cannot be recharged.

36. It should be noted that on occasions WLAB are sometimes classified incorrectly under HS code 780200 that is the designation for scrap lead and general lead waste.

### 2. Heavy Metals Protocol

37. The objective of the 1998 Protocol on Heavy Metals to the 1979 Convention on Long-Range Transboundary Air Pollution, which was amended in 2012, is to control anthropogenic emissions of heavy metals, including lead, that are likely to have significant adverse human health or environmental effects. Parties to the Protocol are required to reduce emissions of target heavy metals below 1990 levels (or an alternative year between 1985 and 1995) by applying best available techniques for stationary sources and imposing emissions limit values for certain stationary sources. Parties are also required to develop and maintain emission inventories for heavy metals covered under the Protocol. Annex VII to the Protocol requires the development and implementation of programmes for the collection, recycling or disposal of products containing one of the heavy metals listed in Annex I in an environmentally sound manner to minimise the impact on human health and the environment.

### 3. SAICM

38. The Strategic Approach to International Chemicals Management (SAICM) is made up of a ministerial declaration (the "Dubai Declaration on International Chemicals Management"), an overarching policy strategy, and a global plan of action. A quick start programme (QSP) was established under SAICM in 2006 to support initial enabling capacity-building and implementation activities in developing countries, least developed countries, small island developing states and countries with economies in transition (UNEP, 2006a). The QSP was closed in December 2019[6]. One of the policy issues covers lead with the overall aim of eliminating its use in paint.

### 4. UNEP Global Lead-acid Batteries Programmes

39. The UNEP Global lead acid battery programme aims to promote the environmentally sound management of waste lead acid batteries through resolutions and plans/programmes. As part of this work UNEP conducted a needs assessment survey to identify the challenges[7].

40. A survey was conducted in 102 countries to ascertain their status on waste lead acid batteries, regulations in place, monitoring manufacturing, recycling and trade processes involved with waste lead-acid batteries, as well as specific country needs to enhance and strengthen institutions to manage this issue in a more environmentally sustainable manner.

41. From the responses the results identified the following regional needs:

(a) Asia and the Pacific region expressed need for technical and capacity building as most required;

(b) Latin American region expressed more needs for monitoring system, national strategy, technical and capacity building, legislation and regulation building;

(c) Africa region expressed needs for monitoring system, public private partnership, technology, and legislation and regulation building.

42. UNEP has also undertaken a pilot project in Bangladesh through the provision of technical assistance and capacity building activities. The project aims to establish the basis for environmentally sound management. A key output has been to assist in the drafting of a national strategy setting out

[5] http://www.miratrans.am/myfiles/files/files/HS%20Codes.pdf.

[6] http://www.saicm.org/portals/12/Documents/QSP/QSPFactsheet.pdf.

[7] https://www.unep.org/explore-topics/chemicals-waste/what-we-do/emerging-issues/lead-acid-batteries.

clear goals and agreed strategies that Government and civil society organisations can model their programmes on.

### 5. Organisation for Economic Co-operation and Development

43. OECD has adopted a recommendation on ESM of waste that covers such items as the core performance elements of ESM guidelines applying to waste recovery facilities, including: elements of performance that precede collection, transport, treatment and storage; and elements subsequent to storage, transport, treatment and disposal of pertinent residues (OECD, 2004).

44. Further information may be found in the guidance manual for the implementation of the OECD recommendation on ESM of waste (OECD, 2007)[8].

### 6. International Labour Organisation (ILO)

**Commented [CV10]:** On behalf of the consultant: Including the ILO, which is a UN agency, here demonstrates the international linkage for the ESM of WLAB relating to worker health & safety and the protection of communities

#### (a) ILO Chemical Conventions & Recommendation, 1990

45. The ILO Chemical Convention was established to ensure the protection of the environment, the public and all those working with chemicals and at the 77th session of the ILO it was approved on 6 June 1990. As part of the convention the Chemicals Recommendation, 1990 was adopted to supplement the Chemicals Convention 1990[9].

46. The convention contains several provisions giving employees the right to be consulted on the measures to protect them. Under the convention the competent authority should specify the categories of workers who for reasons of health and safety are not allowed to use specified chemicals or to use them under certain conditions. The provisions also apply to self-employed people.

47. The Convention covers the following:

(a) Classification of chemicals;

(b) Labelling and marking;

(c) Chemical safety data sheets;

(d) Responsibilities of employers;

(e) Operational controls;

(f) Medical surveillance;

(g) First aid and emergencies;

(h) Rights of employees.

48. The list of classified chemicals includes lead, and it is specifically mentioned due to its environmental and health effects. Consequently, under the convention and recommendations it forms an important basis for the ESM of WLAB.

#### (b) ILO Code of Practice – safety & health

49. The International Labour Organisation has developed a code of practice that provides governments with global guidelines, based on international labour standards and best practice, for addressing specific occupational hazards and this includes lead and the recycling of waste lead-acid batteries. The code aims to ensure that the safety and health of all those involved non-ferrous metals production and recycling, in large and small enterprises are protected from exposure to workplace hazards. The ILO considers the provisions of the code to represent the minimum standards and where more stringent applicable standards apply, they should have priority.

50. The code, which deals with the production of metal in bulk, focuses on foundries and on the production of primary non-ferrous metals, including from recycled material. It does not deal with mining, nor does it address the fabrication of commercial products made from non-ferrous metals[10].

51. This code was adopted unanimously by a Meeting of Experts on Safety and Health in the Non-ferrous Metals Industries, held in Geneva from 28 August to 4 September 2001. It paves the way for developing a consensus on a comprehensive and practical code that is useful for all those working in

[8] https://www.oecd.org/env/39559085.pdf#:~:text=On%209%20June%202004%2C%20the%20OECD%20Council%20adopted,Waste%20Prevention%20and%20Recycling%20%28WGWPR%29%20%28as%20of%202001%29.

[9] https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C170.

[10] https://www.ilo.org/global/topics/safety-and-health-at-work/normative-instruments/code-of-practice/WCMS_107713/lang--en/index.htm.

the non-ferrous metals industries. The Governing Body of the ILO approved the publication of the code at its 282nd Session (November 2001).

52. The code sets out the general principles of prevention and protection, including the duties of regulatory authorities, employers, and workers. This first part covers a range of topics, including risk assessment, risk management, training, and workplace and health surveillance. The main part of the code identifies and examines a range of physical hazards that are commonly encountered during the production of non-ferrous metals. These include noise, vibration, heat stress, radiation, confined spaces, dust, and chemicals. Separate chapters deal with furnaces, molten metal, and recycling.

# III. Guidance on the environmentally sound management of waste lead-acid batteries

## A. General considerations

Commented [BRS11]: Regarding sections A, B, C

SIWG to consider:
- including information on best practices and the use of IT to help with traceability on the collection of WLAB
- Para 67 - and check whether EPR systems cover ULAB
- Checking the whole section regarding terminology already adopted by BC

53. Environmentally sound management (ESM)[11] is a broad policy concept that is understood and implemented in various ways by different countries, organizations, and stakeholders. The provisions and guidance documents pertaining to the ESM of hazardous wastes and other wastes under the Basel Convention provide for a common understanding and international guidance to support and implement the ESM of hazardous wastes and other wastes. OECD has also produced core performance elements related to ESM.

54. Examples of technical guidelines and standard operating procedures on the environmentally sound management of waste lead-acid batteries that have been developed for regions and countries include those developed by the Commission for Environmental Cooperation in North America and standard operating procedures developed for use in Ghana but with a view for wider use and uptake[12,13].

### 1. Basel Convention

~~53.~~55. The 2013 *Framework for the environmentally sound management of hazardous wastes and other wastes*, adopted by decision BC-11/1 (“ESM framework”) (UNEP, 2013) establishes a common understanding of what ESM encompasses and identifies tools and strategies to support and promote the implementation of ESM. In addition, a set of practical manuals for the promotion of the environmentally sound management of wastes (UNEP, 2017c and UNEP,2019h) has been developed. The ESM framework and manuals are intended as practical guides for governments and other stakeholders participating in the management of hazardous wastes and other wastes and complement the Basel Technical Guidelines. Moreover, guidance on how to address the environmentally sound management of wastes in the informal sector (UNEP, 2019a) and a practical manual for stakeholders to ensure that notifications of transboundary movements meet environmentally sound management requirements (UNEP, 2022f) has been developed.

~~54.~~56. As presented in paragraph 30 of this document, Article 4 of the Basel Convention contains provisions related to the ESM of hazardous wastes and other wastes. ESM is also the subject of the following declarations:

(a) The 1999 Basel Declaration on Environmentally Sound Management, which was adopted at the fifth meeting of the Conference of the Parties to the Basel Convention, calls on the Parties to enhance and strengthen their efforts and cooperation to achieve ESM, including through prevention, minimization, recycling, recovery and disposal of hazardous and other wastes subject to the Basel Convention. This considers social, technological and economic concerns, and through further reduction of transboundary movements of hazardous and other wastes subject to the Basel Convention;

(b) The 2011 Cartagena Declaration on the Prevention, Minimization and Recovery of Hazardous Wastes and Other Wastes was adopted at the tenth meeting of the Conference of the Parties to the Basel Convention. The Declaration reaffirms that the Basel Convention is the primary global legal instrument for guiding the ESM of hazardous wastes and other wastes and their disposal, including efforts to prevent and minimize their generation, and efficiently and safely manage that which cannot be avoided;

(c) The waste management hierarchy is a guiding principle for the ESM of waste and covers prevention, minimization, reuse, recycling, other recovery including energy recovery, and final disposal. The hierarchy encourages treatment options that deliver the best overall environmental outcome, taking into account lifecycle thinking[14] and the circular economy. This approach can make a significant contribution to resource recovery, reduce energy inputs and assist tackling global warming.

[11] http://www.basel.int/Implementation/CountryLedInitiative/EnvironmentallySoundManagement/ESMToolkit/Overview/tabid/5839/Default.aspx.

[12] https://www.sustainable-recycling.org/wp-content/uploads/2022/04/ULAB_recycling_SOPs.pdf

[13] http://www.cec.org/files/documents/publications/11665-environmentally-sound-management-spent-lead-acid-batteries-in-north-america-en.pdf

[14] http://www.basel.int/Implementation/StrategicFramework/Strategicgoalsandobjectives/tabid/3811/Default.aspx.

The waste management hierarchy has also been recognised by the Strategic Framework (adopted by decision BC-10/2), the ESM framework (see its paras. 11, 14, 18, 26 and 43) and in the Guidance to assist Parties in developing efficient strategies for achieving the prevention and minimization of the generation of hazardous and other wastes and their disposal (UNEP, 2017d). The waste hierarchy was also defined and described in UNEP's Global Waste Management Outlook (UNEP, 2015b);

(d) Parties should consider a systemic approach to harmonizing and developing policy frameworks related to waste lead-acid batteries. Such an approach may address health and environmental impacts;

(e) In addition, Parties should develop a range of measures (strategies, legislation, regulations and programmes) and monitor their implementation to support the meeting of ESM objectives. The implementation of national strategies, policies and programmes are effective methods to ensure a structured approach to the implementation of legislation and regulations; monitoring and enforcement; incentives and penalties; technologies; and other tools in which all key stakeholders participate and cooperate (UNEP, 2013). The following sections should be taken into account when establishing, implementing or evaluating ESM.

### 2. Life cycle management of lead-acid batteries

55.57. The concept of life cycle management can serve as a useful approach to promote the ESM of wastes. Life cycle management provides a framework for analysing and managing the sustainability performance of goods and services. Global businesses are using it, for instance, to reduce the carbon, raw material and water footprints of their products, improve their social and economic performance, and make value chains more sustainable (UNEP and SETAC, 2009). When a life cycle management approach is applied to lead-acid batteries, performance should be assessed during the following stages: production of lead-acid batteries, their usesproducts containing lead; the use of those products; collection and transportation of WLABwastes; and their recycling of wastes and their reuse of the recovered wastes.

56.58. In life cycle management of lead-acid batteries, it is important to give priority to minimising its impact during the production of lead and lead-acid batteries, thereby reducing the lead content of wastes and emissions resulting from such the production products and processes and their use. When using products containing lead-acid batteries, special care should be taken not to emit or release pollutants into the environment. -WLAB should be recycled to recover the lead, electrolyte and plastics. Wastes from the recovery process containing lead may be treated to recover the lead in them (e.g., slags, wastewater treatment sludges, bag house dusts, etc.).

57.59. The life cycle of the lead-acid battery from production of lead to the WLAB being recycled and products recovered demonstrates the circular economy in action by minimising the generation of wastes, use of energy and resources through the recyclability of the battery components.

**Commented [BRS12]:** SIWG to consider adding information on the concentration of lead in the batteries covered in this document (cross check with other sections, e.g., paragraph 5)

## B. Legislative and regulatory framework

58.60. Parties to the Basel Convention should examine, where appropriate, their national and subnational strategies, policies, controls, standards, and procedures to ensure that they are in agreement with the Convention and with their obligations under it, including those that pertain to the transboundary movement and ESM of waste lead-acid batteries.

**Commented [CV13]:** On behalf of the consultant: Would it be appropriate to include a section on end of waste criteria?

**Commented [CV14]:** On behalf of the consultant: Can include a reference to the proximity principle and the need to prevent shipments to regions that are cheaper because they have less controls and the need to ship battery plates.

59.61. Most countries already have in place some form of legislation that outlines broad environmental protection principles, powers, and rights. Such legislation should make ESM operational and include requirements for protection of both human health and the environment. Such enabling legislation can give governments the power to enact and enforce specific rules and regulations on the ESM of waste lead-acid batteries, including provisions for inspections and for establishing penalties for violations (e.g., on illegal shipments).

60.62. The legislation should enable relevant authorities to monitor whether facilities where wastes lead-acid batteries are stored, collected, transported, and recycled, have obtained all the necessary approvals, and can demonstrate due diligence in compliance to ensure such facilities are fully protective of human health and the environment. In addition, any legislation should establish whether those involved in waste lead-acid battery management (e.g., generators, collectors, transporters, and recyclers) ensure that the collection, transportation, storage and recycling and disposal of any wastes are environmentally sound.

61.63. Specific components or features of a regulatory framework that would meet the requirements of the Basel Convention and other international agreements are addressed in relevant guidance documents developed under these conventions[15]. The legislative and regulatory approach to adopting a sound ESM for WLAB should include the following:

(a) Registration of waste generators;

(b) Registration of waste carriers;

(c) Authorisation of waste storage sites;

(d) Authorisation of waste recycling facilities.

### 1. Extended producer responsibility

64. Extended producer responsibility (EPR) is defined as "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle". "Producer"[16] is considered to be the brand owner or importer except in cases such as packaging, and in situations where the brand owner is not clearly identified, as in the case of electronics, in which the manufacturer (and importer) would be considered as the producer (OECD, 2001a). EPR programmes shift the responsibility for the end-of-life management of products from local government authorities and taxpayers to producers, and can create incentives for producers to incorporate environmental considerations into the design of their products and ensure that the cost of environmentally sound treatment and disposal of those products once they have become waste are reflected in product prices. EPR can be implemented through mandatory or voluntary approaches, or a combination of the two (e.g., via negotiated agreements). Take-back collection programmes can be incorporated into EPR programmes.

65. EPR programmes, depending on how they are designed, can achieve a number of objectives, including: (1) to relieve local governments of the financial and in some cases operational burden of disposing of waste/products/materials; (2) to encourage companies to design products for reuse and recyclability and to reduce both the quantity and hazardousness of materials used; (3) to incorporate waste management costs into product prices; and (4) to promote innovation in recycling technology. EPR therefore promotes a market in which prices reflect the environmental costs of products (OECD 2001a). Detailed descriptions of EPR schemes are available in several OECD publications on the issue[17].

66. When EPR programmes are used, the environmental authorities may develop regulatory frameworks setting out the responsibilities of relevant stakeholders, standards for the management of products and the components that all EPR programmes should have and encourage participation by relevant parties and the public. The environmental authorities should also monitor the performance of EPR programmes (e.g., amount of wastes collected, amount of WLAB recycled and costs accrued for collection, recycling and storage) and make recommendations for improvement as necessary. The responsibility to implement EPR programmes should be shared by all producers of a given product and there should be no "free riders" (i.e., producers who do not have to implement EPR) in such programmes to avoid a situation in which certain producers are forced to bear a disproportionate share of the costs of EPR that goes beyond their product market share.

67. Extended producer responsibility schemes do not typically include waste lead acid batteries given the fact there is a value to the lead, plastic and acid. As such financial incentives already exist (i.e., lead price) to encourage recycling. Should the market for lead change and it no longer becomes economically viable to recycle then consideration can be given to the development and possible introduction of an extended producer responsibility scheme. The introduction of an EPR scheme will also depend on the local situation and as such there may be a case for the authorities to require such a scheme being in operation.

### ~~1.~~2. Registration of waste generators

~~62.~~68. An approach to facilitate ESM of WLAB involves the establishment, through regulation, of registers of generators of this type of waste[18]. Such registers should include:

(a) Garages/retailers with collection/take-back facilities;

(b) Recycling centres;

[15] http://www.basel.int/TheConvention/Publications/GuidanceManuals/tabid/2364/#.

[16] European Union Directive 2008/98/EC provides that any natural or legal person who professionally develops, manufactures, processes, treats, sells or imports products has extended producer responsibility.

[17] Available at: http://www.oecd.org/env/tools-evaluation/extendedproducerresponsibility.htm.

[18] https://www.gov.uk/hazardous-waste-producer-registration-wales.

(c) Battery manufacturers/importers/distributors;

(d) Industrial/commercial/public sector WLAB producers (e.g., telecoms, public utilities, hospitals, transport companies).

63.69. Regulations on registries of generators of WLAB could require waste generators to provide their name, address, the name of the responsible person, their type of business, the quantities of waste generated, and information on any collection schemes, if applicable to these wastes and how the wastes are to be handed over to collectors and sent for recycling. Waste generators could be required to transmit and provide regular updates on this information to the authorities (central or local governments). Based on the amounts and kinds of waste obtained through registries, Parties could also develop waste inventory programmes.

64.70. WLAB generators should have a duty to prevent emissions and releases to the environment until the wastes are handed over to collectors or sent to a recycling facility. To prevent environmental releases WLAB should be stored in containers that meet approved standards. They should strictly comply with national and local legal requirements regarding the management of WLABs and be held liable for remediating or compensating any environmental or health damages that they might cause when handling such wastes, to the degree required by applicable legislation. Large scale waste generators should be subject to inspection and checks to ensure they are complying with the appropriate legislative requirements.

### 2.3. Registration of waste carriers

**Commented [CV15]:** On behalf of the consultant: The registration of waste carriers offers an effective means over esm movements of waste and who is moving WLAB - this is something that should be included in other TGs rather than suggesting this is not included in this document as a specific section.

65.71. Waste carriers, i.e., anyone who normally collects, carries or transports waste in the course of any business or with a view to profit who collect and transport hazardous wastes, such as WLAB, should be required to register with the authorities[19]. Often authorities maintain registers of the carriers and issues licenses which enables them to inspect and check that ESM practices are being adhered to, such as WLAB being transported correctly, so that the batteries are protected from damage and short circuits, preventing leakage of electrolyte, and emissions of lead containing materials, the appropriate labels are being clearly displayed on the packaging and vehicle that indicate the type of substance and associated hazards. Waste carriers should be subject to inspection and checks to ensure they are complying with the appropriate legislative requirements.

### 3.4. Requirements of temporary waste storage facilities ~~sites~~

66.72. To ensure that WLAB storage facilities comply with ESM legislation should be developed setting out specific conditions for their safe storage such as types of containers to be used, how they should be stored, storing waste in a secure place to prevent environmental releases, labelling containers, use of covers to prevent rain water ingress and contamination run-off, hazard signage, facility construction requirements (e.g., storing waste on an impermeable floor), monitoring and inspection requirements[20].

### 4.5. Requirements ~~Authorisation~~ of waste treatment & recycling facilities

67.73. Most countries have legislation in place that require the operators of waste treatment and recycling facilities to obtain approval to operate[21]. Approvals should contain specific conditions that should be adhered to for these approvals to remain valid. A permitting or approval process based on established and transparent criteria on, inter alia, how to operate facilities, emission levels, monitoring, as well as an inspection regime may be an appropriate approach. It may prove necessary to add requirements specific to WLAB to meet the requirements of ESM, and to comply with the specific requirements of the Basel Convention.

74. Environmental impact assessments (EIA) are often required ~~Transboundary movement~~to be undertaken to establish the likely environmental effects of new projects such as hazardous waste recycling plants, lead-acid battery manufacturing plant and modifications to existing operations. The EU, for example, has a Directive (Directive 2011/92/EU) setting out its requirements for undertaking an EIA and what is be covered. The authorities require the companies who are planning to operate the plant or make the modifications to undertake the EIA themselves and submit it to the authorities for review and assessment prior to obtaining approval for a licence setting out the conditions of operation and compliance requirements.

**Commented [BRS16]:** SIWG to consider adding information on minimal requirements in respect to environmental impact assessment.

[19] https://www.gov.uk/register-renew-waste-carrier-broker-dealer-england.

[20] https://www.gov.uk/guidance/waste-environmental-permits.

[21] https://www.epa.gov/hwpermitting/what-hazardous-waste-permit#:~:text=All%20facilities%20that%20currently%20treat%2C%20store%20or%20dispose,they%20can%20manage%20hazardous%20waste%20safely%20and%20responsibly.

75. Guidance on the requirements for an EIA to be conducted are usually published including guidance on screening and the detailed requirements of what should be covered and included in an EIA report. An example of screening procedure booklet is one produced by the UK Environment Agency.

76. The UK, for example, requires a screening exercise to be undertaken to address size, cumulation with other developments, use of natural resources, production of waste, pollution and nuisances, risk of accidents and locations (e.g. wetlands, coastal zones, forest areas, nature reserves and parks, special environmentally designated areas, where environmental quality standards are exceeded and landscapes of historical, cultural or architectural importance) to determine which projects require an EIA. Also, the characteristics of the impact need to be considered (e.g., trans-boundary, magnitude, complexity and probability).

77. Site selection for any new WLAB recycling plant is important to minimize environmental, health and safety risks. It is important to assess potential emissions impacts to the areas around the plant for example, aquifers, groundwater, surface water, farmland, residential areas, businesses, and facilities such as hospitals, schools and processing plants (e.g., food manufacturers). Consideration of factors such as climate, seismic activity, and topography should also be taken into account to assess potential risks from earthquakes, eruptions, flooding, landslides, rock falls, avalanches, and tidal surges. As part of the planning process there is a need to take into account the availability of energy sources, water, emergency services, road links, etc.

78. For existing plant, it is important that future residential and commercial developments do not encroach on the plant to avoid environmental, health and safety risks. In addition it would be advisable to regularly review compliance with best practice in relation to their siting and location and review monitoring data to assess whether any engineering improvements/mitigating measures can be adopted to minimise any potential impacts.

## 6. Transboundary movement requirements

79. ~~requirements~~Transboundary movements of hazardous wastes and other wastes should be kept to a minimum consistent with their environmentally sound and efficient management and conducted in a manner that protects human health and the environment from any adverse effects that may result from such movements. Y31 (lead and lead compounds) in Annex I and A1160 (waste lead-acid batteries crushed or whole) in Annex VIII are categorized as hazardous wastes under Article 1, paragraph 1and should, as far as is compatible with their ESM, be disposed of in the country where they were generated (i.e proximity principle22). Under the environmentally sound management of WLAB shipments should go to locations which meet the requirements set out in the technical guidance. These are in line with UNEP's Seven Pillars for the ESM of hazardous waste23.

~~68.~~80. Transboundary movements of lead and lead compounds and WLAB~~suchsuch~~ wastes are permitted only under the following conditions:

(a) If the country of export does not have the technical capacity and the necessary facilities, capacity or suitable disposal sites in order to dispose of the wastes in question in an environmentally sound and efficient manner;

(b) If the wastes in question are required as a raw material for recycling or recovery industries in the country of import;

(c) If the transboundary movements in question are in accordance with other criteria decided by the Parties;

(d) Any transboundary movements of hazardous wastes and other wastes considered under the Basel Convention are subject to prior written notification from the exporting country and prior written consent from the importing and, if appropriate, transit countries. Parties shall not permit the export of hazardous wastes and other wastes if the country of import prohibits the import of such wastes in accordance with the Basel Convention;

(e) Parties listed in Annex VII to the Convention (members of the EU, OECD and Liechtenstein), that are bound by the Ban Amendment, shall prohibit transboundary movements to states not listed in Annex VII of hazardous wastes which are destined for operations according to

[22] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF
[23] https://www.unep.org/resources/report/guidance-manual-policymakers-and-regulators-environmentally-sound-management-waste



**Commented [CV17]:** On behalf of the consultant: Added battery breaking and sending transboundary shipments of plates and pastes not best practice - proximity principle to be included to minimise shipments to regions where it is cheaper to recover metals etc because of lesser HSE controls.

Annex IVA and hazardous wastes under Article 1.1(a) which are destined to operations according to Annex IVB[24];

(f) The Basel Convention also requires that information regarding any proposed transboundary movement of hazardous wastes and other wastes be provided using the accepted notification form and that the approved consignment be accompanied by a movement document from the point where the transboundary movement commences to the point of disposal. Furthermore, hazardous wastes and other wastes subject to transboundary movements should be packaged, labelled and transported in conformity with international rules and standards[25];

(g) When a transboundary movement of hazardous wastes and other wastes to which consent of the countries concerned has been given cannot be completed, the country of export shall ensure that the waste in question is taken back into the country of export for their disposal if alternative arrangements cannot be made. In the case of illegal traffic (as defined in Article 9, paragraph 1), as the result of conduct on the part of the exporter or the generator, the country of export shall ensure that the wastes in question are taken back into the country of export for their disposal or otherwise disposed of in accordance with the provisions of the Basel Convention (as per Article 9, paragraph 2). For further information, see the Guidance on the implementation of the Basel Convention provisions dealing with illegal traffic, adopted by COP13 in 2017 (UNEP, 2017g);

(h) No transboundary movements of hazardous wastes and other wastes are permitted between a Party and a non-Party to the Basel Convention unless a bilateral, multilateral or regional [agreement or] arrangement exists as required under Article 11 of the Convention.

### ~~5.~~7. Other legislative controls

~~69.~~81. Examples of other aspects of the management of WLAB that can be regulated through legislation and or a permitting/approval process include:

(a) Environmental impact assessment of facilities handling/recycling WLAB[26];

(b) Siting provisions and requirements relative to the storage, handling, collection, transportation and recycling of WLAB;

(c) Public participation in the permitting or approval process for WLAB treatment facilities as referred to in section III, J;

(d) Requirements for health and safety of workers and protection of the local community;

(e) Decommissioning requirements for WLAB facilities, including:

- (i) Inspection prior to and during decommissioning;
- (ii) Procedures to be followed to protect worker and community health and the environment during decommissioning;
- (iii) Post-decommissioning site requirements;

(f) Emergency contingency planning, spill and accident response, including:

- (i) Clean-up procedures and post-clean-up concentrations to be achieved;
- (ii) Worker training and safety requirements;
- (iii) Waste prevention, minimization and management plans;
- (iv) Obligations to ensure best-practice management systems and operating procedures[27], including requirements for annual reporting and regular third-party auditing and verification after an incident;

(g) Restrictions on greenhouse gas (GHG) emissions across the life cycle lead-acid batteries including their management as wastes, including such restrictions as are required to meet nationally determined contributions for parties to the Paris Agreement.

**Commented [BRS18]:** SIWG to consider including more text on this topic.

[24] http://www.basel.int/Countries/StatusofRatifications/BanAmendment/tabid/1344/Default.aspx.
[25] https://unece.org/transport/publications/recommendations-transport-dangerous-goods-model-regulations-rev22.
[26] https://environment.ec.europa.eu/law-and-governance/environmental-assessments/environmental-impact-assessment_en.
[27] https://www.sustainable-recycling.org/wp-content/uploads/2022/04/ULAB_recycling_SOPs.pdf

## C. Waste prevention and minimization

### 1. General considerations

82. Prevention and minimization of wastes are the most important steps in the waste management hierarchy. The Basel Convention affirms that the most effective way of protecting human health and the environment from the dangers posed by hazardous wastes and other wastes is the reduction of their generation to a minimum in terms of quantity and/or hazard potential.

83. In Article 4, paragraph 2, the Basel Convention calls on Parties to "ensure that the generation of hazardous wastes and other wastes is reduced to a minimum". Waste prevention should be the preferred option in any waste management policy, so that the need for waste management is reduced, enabling resources to be used more efficiently.

84. At the tenth meeting of the Conference of the Parties to the Basel Convention, the Parties, in adopting the Cartagena Declaration committed "to enhancing the active promotion and implementation of more efficient strategies to achieve prevention and minimization of the generation of hazardous waste and other wastes and their disposal".

85. According to the ESM framework, the need to manage wastes and/or the risks and costs associated with waste management can be reduced by not generating wastes and by ensuring that generated wastes are less hazardous (UNEP, 2013).

86. The ESM framework states that "companies that generate wastes (waste generators) are responsible for ensuring the implementation of best available techniques (BAT) and best environmental practices (BEP) when undertaking activities that generate wastes". In doing so, they act to minimize the wastes generated by ensuring research, investment in design, innovation and development of new products and processes that use less resources and energy and that reduce, substitute or eliminate the use of hazardous materials (UNEP, 2013).

87. A practical manual on waste prevention, as part of the set of practical manuals for the promotion of the environmentally sound management of wastes (UNEP, 2017c), provides stakeholders with general guidance on waste prevention principles, strategies and possible measures and tools. The Guidance to assist Parties in developing efficient strategies for achieving the prevention and minimization of the generation of hazardous wastes and other wastes and their disposal (UNEP 2017d) identifies elements of a waste prevention and minimization programme.

## ~~C~~D. Identification and inventory

### 1. Identification of sources of WLAB

~~70.~~88. The identification of possible numbers and types of batteries in use, how they are being used, how long they are lasting before reaching the end of life, is the starting point for an effective ESM. To enable effective action to prevent/minimize environmental and health effects associated with improper handling and recycling of WLAB it is important to identify the sources of waste lead-acid batteries and likely quantities generated.

### 2. Inventories

~~71.~~89. Inventories can be an important tool for identifying, quantifying, and characterizing WLAB arisings. When developing an inventory for WLAB priority should be given to the identification of the potential significant producers and recyclers such as high volume wastes, areas of greatest concern e.g. areas with significant environmental and health concern (e.g. informal recycling sector).

~~72.~~90. National inventories may be used:

(a) To establish a baseline quantity of lead acid battery manufacturers, importers, exporters, retailers, distributors, WLAB producers, WLAB collectors, WLAB transporters, WLAB exporters and WLAB recyclers (formal and informal sector);

(b) To establish an information registry to assist with health, safety and regulatory inspections;

(c) To assist with the preparation of emergency response plans;

(d) To track progress towards minimizing environmental and health concerns;

(e) To provide information for the development of policies, targets and measures to improve the ESM of WLAB.

~~73.~~91. For further information on the development of national inventories Parties may consult the methodological guide for the development of inventories of hazardous wastes and other wastes under the Basel Convention. (UNEP, 2015c). The guide focuses on the actions recommended to develop the national information systems that produce the information needed to assist countries in fulfilling their reporting obligations under the Basel Convention.

### 3. Developing a national management ~~action~~ plan for the ESM of WLAB

**Commented [CV19]:** On behalf of the consultant: This was suggested in the index that was developed for the consultant to work on.

~~74.~~92. The development of a national management ~~action~~ plan for the ESM of WLAB should be based on a review of the existing situation especially where there are limited controls and regulations and limited information on their management. A Guidance Manual of this process has been developed, by UNEP, for policy makers and regulators in Africa for the ESM of WLAB[28]. Information from the data obtained in identifying the sources of WLAB and inventories will greatly assist this process. The review should form the basis for establishing an action plan which may cover the following:

(a) Identify key areas of concern: problematic areas need to be identified where waste lead-acid batteries are recycled by conducting a baseline assessment to identify the locations, as well as the current causes, extent and impacts of their activities;

(b) Evaluate the appropriateness of possible actions: consider the options to tackle potential issues (e.g., regulatory, economic, public awareness, voluntary actions, management procedures), based on the socio-economic state and appropriateness for addressing the specific problems identified;

(c) Assess the options: assessment of the potential social, economic and environmental impacts (positive and negative) of the preferred short-listed instruments/actions. How will the poorest be affected? What impact will the preferred course of action have on different sectors and industries?

(d) Stakeholder engagement: identify and engage with key stakeholder groups (e.g. retailers, consumers, battery manufacturers, industry representatives, local government, manufacturers, civil society, environmental groups and others) to ensure a broad buy-in. Evidence-based studies should assist in presenting the case.

(e) Raise public awareness: the public should be made aware of the health and environmental issues associated with WLAB recycling. Establish a public awareness strategy and implementation;

(f) Training regulators: training for government officials, regulators and other relevant actors (NGOs) need to be included to raise awareness and a better understanding of the issues and to address the technical aspects required for the sustainable, safe and environmentally sound recycling system for WLAB in a manner that minimizes the health and environmental impact to lead exposure. The training should include guidance on how to assess the environmental performance of recycling sites and evaluate associated public and occupational health risks;

(g) Incentives: assess the need to provide support and incentives to industry and organisations involved in the handling, collection, storage, and recycling of WLAB;

(h) Implementation: it is important that progress is monitored, and the effectiveness of the regulations and enforcement are reviewed and adjusted or updated where any issues are identified. It is important for governments to keep the public updated on the progress and benefits achieved, to continue building consensus and demonstrate accountability. It is advisable to review the policy instruments on a regular basis. In the case of regulatory enforcement, it is important to ensure that the WLAB recycling is not illegally carried out in remote areas;

(i) Monitoring: for monitoring and supervision of the ESM of WLAB recycling, it is important to clearly define roles and responsibilities between local, national and sub-national authorities and organizations beforehand. To gather data on effectiveness, governments may consider including in the legislation a reporting obligation. Progress can be assessed in several ways, including health, safety and environmental (HSE) audits, surveys, impact assessments and stakeholder feedback.

## E~~D~~. Sampling, analysis and monitoring

**Commented [BRS20]:** SIWG to consider adding more references on this section, e.g., in relation to the informal sector, standards.

~~75.~~93. Sampling, analysis and monitoring are critical components of lead waste management and should be conducted by trained professionals in accordance with well-designed programmes using internationally accepted or nationally approved methods and should be carried out using the same methods throughout the lives of such programmes. They should also be subjected to rigorous quality

[28] https://www.unep.org/resources/report/guidance-manual-policymakers-and-regulators-environmentally-sound-management-waste

assurance and quality control measures. Mistakes in sampling, analysis or monitoring or deviation from standard operational procedures can result in meaningless data or even programme-damaging data. Each party, as appropriate, should therefore develop standards to ensure that training, protocols and laboratory capabilities are in place for sampling, monitoring and analytical methods and that those standards are enforced.

~~76.~~94. Because there are numerous reasons for sampling, analysing and monitoring and because waste comes in so many different physical forms, many different sampling, analysis and monitoring methods are available. Although it is beyond the scope of this document to discuss them specifically, the next three sections consider key elements that should be included in sampling, analysis and monitoring activities.

~~77.~~95. For information on good laboratory practices, the OECD series on good laboratory practice (OECD, various years) may be consulted.

### 1. Sampling

~~78.~~96. The overall objective of any sampling activity is to obtain a sample that can be used for a targeted purpose, e.g., site characterization, compliance with regulatory standards or determination of the suitability of proposed treatment or disposal methods. This objective should be identified before sampling is started. It is indispensable that quality requirements for equipment, transportation and traceability be met.

~~79.~~97. Standardized sampling procedures should be established and agreed upon before the start of the sampling campaign. Elements of these procedures may include the following:

(a) The number of samples to be taken, the sampling frequency, the duration of the sampling project and a description of the sampling method to be used (including quality assurance procedures put in place, e.g., use of appropriate sampling containers and field blanks and of chain-of-custody procedures);

(b) Selection of locations or sites at which lead wastes are generated and time and date of sample-taking (including description and geographic localization);

(c) Identity of person who took the sample and conditions during sampling;

(d) Full description of sample characteristics – labelling;

(e) Preservation of the integrity of samples during transport and storage (before analysis);

(f) Close cooperation between the sampler and the analytical laboratory;

(g) Appropriately trained sampling personnel.

~~80.~~98. Sampling should comply with specific national legislation, where it exists, or with international regulations and standards. In countries where regulations do not exist, qualified staff should be appointed. Sampling procedures include the following:

(a) Development of a standard operational procedure (SOP) for sampling each of the matrices for lead analysis;

(b) Application of well-established sampling procedures such as those developed by the International Organization for Standardization (ISO), the European Committee for Standardization (CEN), the United States Environmental Protection Agency (USEPA), the Global Environment Monitoring System (GEMS) and the American Society for Testing and Materials (ASTM);

(c) Establishment of quality assurance and quality control (QA/QC) procedures.

~~81.~~99. All these steps should be followed if sampling programmes are to be successful. Similarly, documentation should be thorough and rigorous.

~~82.~~100. Lead can occur and be sampled in liquids, solids, gases and biota:

(a) Liquids:

(i) Leachate from landfills;

(ii) Liquid collected from spills;

(iii) Water (surface water, drinking water and industrial effluents);

(b) Solids:

(i) Stockpiles of WLAB;

(ii) Solids from industrial sources and treatment or disposal/recycling processes (waste slags, contaminated equipment, containers, redundant equipment, residues, etc.);

(iii) Soil, sediment, rubble, wastewater treatment sludge;

(c) Gases:

(i) Air (indoor) of facilities handling WLAB;

(ii) Leady releases to the air from recycling/treatment activities;

(iii) Flue gas from ventilation and extraction systems;

(d) Biota:

(i) Biological materials (blood samples obtained through employee health monitoring);

(ii) Flora and fauna.

~~83.~~101. In environmental and human monitoring programmes, both biotic and abiotic matrices may be included:

(a) Plant materials and food;

(b) Blood samples;

(c) Air (ambient, wet or dry deposition or, possibly, snow).

### 2. Analysis

~~84.~~102. Analysis relates to the extraction, purification, separation, identification, quantification and reporting of lead concentrations in the matrix of interest. In order to obtain meaningful and acceptable results, the analytical laboratory should have the necessary infrastructure (housing) and proven experience with the matrix and lead (e.g., successful participation in inter-laboratory comparison studies and in external proficiency testing schemes).

~~85.~~103. Accreditation of the laboratory in accordance with ISO 17025 or other standards by an independent body is important. Essential criteria for obtaining high-quality results include:

(a) Specification of the analytical technique used;

(b) Maintenance of analytical equipment;

(c) Validation of all methods used (including in-house methods);

(d) Training of laboratory staff.

~~86.~~104. As with all chemical analysis, laboratories should use only validated methods, and performance should be evaluated through QA/QC programmes.

### 3. Monitoring

~~87.~~105. In Article 10 ("International Cooperation"), paragraph 2 (b), the Basel Convention requires Parties to "cooperate in monitoring the effects of the management of hazardous wastes on human health and the environment".

~~88.~~106. Monitoring programmes should be implemented for facilities managing/handling/recycling WLAB, as they provide an indication of whether a facility is operating in accordance with its design and environmental regulations. The information obtained through monitoring programmes should be used to ensure that WLAB are properly managed, to identify potential issues relating to possible lead releases or exposure to lead and other substances to determine whether amendments to the management approach might be appropriate.

## ~~E. Waste prevention and minimization~~

### ~~General considerations~~

~~Prevention and minimization of wastes are the most important steps in the waste management hierarchy. The Basel Convention affirms that the most effective way of protecting human health and the environment from the dangers~~

posed by hazardous wastes and other wastes is the reduction of their generation to a minimum in terms of quantity and/or hazard potential.

In Article 4, paragraph 2, the Basel Convention calls on Parties to "ensure that the generation of hazardous wastes and other wastes is reduced to a minimum". Waste prevention should be the preferred option in any waste management policy, so that the need for waste management is reduced, enabling resources to be used more efficiently.

At the tenth meeting of the Conference of the Parties to the Basel Convention, the Parties, in adopting the Cartagena Declaration committed "to enhancing the active promotion and implementation of more efficient strategies to achieve prevention and minimization of the generation of hazardous waste and other wastes and their disposal".

According to the ESM framework, the need to manage wastes and/or the risks and costs associated with waste management can be reduced by not generating wastes and by ensuring that generated wastes are less hazardous (UNEP, 2013).

The ESM framework states that "companies that generate wastes (waste generators) are responsible for ensuring the implementation of best available techniques (BAT) and best environmental practices (BEP) when undertaking activities that generate wastes". In doing so, they act to minimize the wastes generated by ensuring research, investment in design, innovation and development of new products and processes that use less resources and energy and that reduce, substitute or eliminate the use of hazardous materials (UNEP, 2013).

A practical manual on waste prevention, as part of the set of practical manuals for the promotion of the environmentally sound management of wastes (UNEP, 2017c), provides stakeholders with general guidance on waste prevention principles, strategies and possible measures and tools. The Guidance to assist Parties in developing efficient strategies for achieving the prevention and minimization of the generation of hazardous wastes and other wastes and their disposal (UNEP 2017d) identifies elements of a waste prevention and minimization programme.

### 6.1. Extended producer responsibility

89.1. Extended producer responsibility (EPR) is defined as "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle". "Producer"[29] is considered to be the brand owner or importer except in cases such as packaging, and in situations where the brand owner is not clearly identified, as in the case of electronics, in which the manufacturer (and importer) would be considered as the producer (OECD, 2001a). EPR programmes shift the responsibility for the end-of-life management of products from local government authorities and taxpayers to producers, and can create incentives for producers to incorporate environmental considerations into the design of their products and ensure that the cost of environmentally sound treatment and disposal of those products once they have become waste are reflected in product prices. EPR can be implemented through mandatory or voluntary approaches, or a

[29] European Union Directive 2008/98/EC provides that any natural or legal person who professionally develops, manufactures, processes, treats, sells or imports products has extended producer responsibility.

combination of the two (e.g., via negotiated agreements). Take-back collection programmes can be incorporated into EPR programmes.

90.1. EPR programmes, depending on how they are designed, can achieve a number of objectives, including: (1) to relieve local governments of the financial and in some cases operational burden of disposing of waste/products/materials; (2) to encourage companies to design products for reuse and recyclability and to reduce both the quantity and hazardousness of materials used; (3) to incorporate waste management costs into product prices; and (4) to promote innovation in recycling technology. EPR therefore promotes a market in which prices reflect the environmental costs of products (OECD 2001a). Detailed descriptions of EPR schemes are available in several OECD publications on the issue[30].

91.1. When EPR programmes are used, the environmental authorities may develop regulatory frameworks setting out the responsibilities of relevant stakeholders, standards for the management of products and the components that all EPR programmes should have and encourage participation by relevant parties and the public. The environmental authorities should also monitor the performance of EPR programmes (e.g., amount of wastes collected, amount of WLAB recycled and costs accrued for collection, recycling and storage) and make recommendations for improvement as necessary. The responsibility to implement EPR programmes should be shared by all producers of a given product and there should be no “free riders” (i.e., producers who do not have to implement EPR) in such programmes to avoid a situation in which certain producers are forced to bear a disproportionate share of the costs of EPR that goes beyond their product market share.

92.1. Extended producer responsibility schemes do not typically include waste lead acid batteries given the fact there is a value to the lead, plastic and acid. As such financial incentives already exist (i.e., lead price) to encourage recycling. Should the market for lead change and it no longer becomes economically viable to recycle then consideration can be given to the development and possible introduction of an extended producer responsibility scheme. The introduction of an EPR scheme will also depend on the local situation and as such there may be a case for the authorities to require such a scheme being in operation.

## F. Handling, separation, collection, packaging, labelling, transportation and storage

### 1. General Considerations

93.107. The procedures for the handling, separation, collection, packaging, labelling, transportation and storage of WLAB pending their recycling are generally similar to those applicable for hazardous wastes. However, because of the health and environmental impact of lead, the ESM of WLAB requires the use of particular precautions to prevent the release of lead.

94.108. Specific guidance on the most appropriate handling of WLAB is provided in this section, but it is important that generators also consult and adhere to applicable national and local requirements and follow best management practices and adopt standard operating procedures to be used as a guide for environmental and workplace performance[31]. For transport and the transboundary movement of WLAB they are classed as hazardous wastes, the following documents should be consulted to determine specific requirements.

### 2. Handling

95.109. Those who handle WLAB should, taking into consideration relevant national regulations, pay special attention to the prevention of lead and acid releases into the environment.

96.110. End users should safely handle and prevent any breakage of or damage to WLAB. Wastes of products containing lead or lead compounds such as battery plates, slags and residues should be handled safely and should not be discharged onto the unprotected ground or into storm sewers or other rainfall runoff collection systems. WLAB and waste products containing lead should not be mixed with any other wastes. If such products are accidentally broken or spilled, clean-up procedures should be followed.

97.111. To ensure that releases of lead from WLAB are kept to a minimum, it is important to first raise awareness of those involved in handling, separation, collection, packaging, labelling, transportation and storage (e.g., salvagers, transporters, recyclers, and treatment operators) about the

[30] Available at: http://www.oecd.org/env/tools-evaluation/extendedproducerresponsibility.htm.

[31] https://www.sustainable-recycling.org/wp-content/uploads/2022/04/ULAB_recycling_SOPs.pdf

risks of lead. Such awareness raising can be achieved through training, labelling and data information sheets.

### 3. Separation

Commented [BRS21]: SIWG to consider adding information on acid separation.

~~98.~~112. Separation of WLAB is important because if such wastes are simply disposed of, e.g., as part of municipal solid waste (MSW), without any separation, the lead could be released into the environment.

~~99.~~113. Separation is best facilitated through the labelling of batteries showing they contain lead and that they should be recycled and not disposed of in the general waste stream. Labelling systems for batteries should be implemented by battery manufacturers during the production stage to aid their identification and need for recycling. Labels should comply with national regulations, which may require the disclosure of the identity and properties of toxic chemical ingredients in products. Labelling systems for products containing lead should include instructions that encourage recycling. The label should also contain a local telephone help line or multilingual web site where safe disposal or collection information can be obtained.

~~100.~~114. Manufacturers should indicate the presence of lead in products containing lead by using the international chemical symbol, “Pb”, on product labels. For example, in the European Union, the chemical symbol “Pb” must be printed on lead-acid batteries under Directive 2006/66/EC (European Union, 2006). In addition, they should also show the recycling symbol. Several countries have laws or guidelines that impose or suggest minimum standards for labels, but in most countries the labelling requirements are ether based on or are variations of the European Standard for battery labelling contained in the standards defined in EN 50342.

~~101.~~115. In the European Union, Article 21 of the Batteries Directive specifies that all portable and automotive batteries include an image of a crossed-out wheeled bin to indicate that the used battery should not be placed in a domestic rubbish collection bin destined for disposal at a non-hazardous municipal waste disposal site. The symbol size is specified as a percent of battery area on its largest side (3%), except for cylindrical lead-acid batteries, where the symbol should be 1.5% of total surface area. The capacity of all portable and automotive batteries and accumulators is indicated on them in a visible, legible, and in indelible print. Batteries and accumulators containing more than 0,004 % lead, are marked with the chemical symbol for lead.

~~102.~~116. In the USA, many states require battery manufacturers to comply with the guidelines set out by the American National Standards Institute (ANSI) Standard, under guideline ANSI C18.1M-1992[32]. Under these guidelines all batteries must show:

(a) Manufacturer: The name of the battery manufacturer;

(b) ANSI Number: The ANSI/NEDA number of the battery (where appliable);

(c) The day, month and year the battery was manufactured or the month that the guarantee expires;

(d) The nominal battery voltage;

(e) That the positive and negative terminal posts are clearly marked;

(f) Any other warnings or cautions associated with the battery chemistry or use.

~~103.~~117. It is important to separate lead-acid batteries from other batteries such as those containing lithium to prevent those entering the feedstock of the secondary smelters. Mixing WLAB with other batteries can present significant safety hazards with the potential for fires being caused giving rise to potential health and environmental issues.

### 4. Collection schemes

~~104.~~118. To successfully recycle WLABs there is a need for the installation of an appropriate collection and recovery infrastructure. It needs to be well organised as it involves a number of key stakeholders in the supply chain such as battery retailers, garages, battery suppliers, businesses, collection companies, secondary recyclers, and consumers. Given the value of lead and the number of batteries circulating there are financial incentives to recover them.

~~105.~~119. Successful WLAB recycling schemes rely on the fact that the batteries have an economic value due to the high lead content. In addition, the polypropylene battery case and battery acid can be

[32] https://www.nema.org/docs/default-source/standards-document-library/ansi-c18-1m-part-2_2019-contents-and-scope.pdf?sfvrsn=75bd53f_0.

recovered and converted into a saleable product. The financial viability of a recovery and collection scheme depends on a number of factors:

(a) The metal price of the recovered and refined Lead. (LME prices[33]);

(b) Sufficient quantities of WLAB to maintain a viable operation;

(c) The costs of collecting and transporting the WLAB to the recycling plant;

(d) The costs of buying WLAB and the tax regime;

(e) The impact that any informal recycling has on the price of WLAB.

~~106.~~120. There are several established ways of collecting WLAB, these include:

(a) National collection schemes;

(b) Deposit/refund schemes;

(c) Purchase discount schemes;

(d) Municipal waste recycling facilities;

(e) Local collection schemes.

~~107.~~121. Many countries have the dual system of distribution-collection or deposit refund involving manufacturers, retailers, wholesalers, service stations or other retailing points that provide new replacement batteries to users and retain the used ones to be forwarded to formally licensed/authorised collectors who transfer them to licensed recycling plants. One of the key aspects of any collection scheme is the need for effective control measures being implemented at the collection points to prevent accidents that may have the potential to give rise to human exposure and/or environmental damage. Details of good storage practices are included in F7.

~~108.~~122. Those collecting batteries should only transfer/sell them on to a licensed facility that is authorised to recycle WLAB in an environmentally sound operation. Informal lead recycling operations are a key source of lead pollution with the potential to cause significant human health issues and environmental damage. It is therefore important that collectors only transfer WLAB to those operators that follow and practice environmentally sound management recycling procedures and appropriate standards for protecting the occupational health and safety of employees and others in the community.

~~109.~~123. WLAB Collectors or dealers should not break the batteries into separate components and ship or transport the grids or paste separately. Only whole batteries complete with case, electrolyte, plates and paste should be transported to a WLAB recycling facility. There should be no intermediate steps in the process where batteries are broken down and the components separated and sent to another plant in a different location or country unless the plant is authorised to do so and follows environmentally sound management practices.

**(a) National Collection Schemes**

~~110.~~124. These schemes involve collecting WLAB through a dual system of battery distribution and waste battery collection. This scheme revolves around manufacturers, retailers, wholesalers, service stations and other retailing outlets providing new or replacement batteries to consumers and the outlet taking back the old battery to be sent to collection centers or licensed recycling plants. Such a system, also known as reverse logistics, is sustainable because it is based on the economic value of the lead content of the lead battery and can be run by the battery industry without government support. These reverse logistics systems are also being employed as an integral component of Extended Producer Responsibility (EPR) and advocated as a prime example of a circular economy.

~~111.~~125. When a battery is taken to a retailer such as a garage it could be checked prior to replacing it to see whether it actually needs replacing. The retailer may be able to undertake a safety check and functionality test to confirm whether it needs replacing or can be recharged. In some places they may able to recharge the battery as well.

**(b) Deposit / Refund Schemes**

~~112.~~126. In a number of countries governments have initiated, in cooperation with the battery industry, collection systems based on a financial incentive to return a WLAB, such as a refundable

[33] https://www.lme.com/en-gb/metals/non-ferrous/lead/#tabIndex=0.

levy on new batteries, which is repaid to the customer when the old battery is returned to the retailer. Countries have used these financial incentives as shown in the following examples:

(a) USA - Several States require payment of a deposit of USD 5 to 10 on the purchase of all new lead acid automotive batteries. The deposit on the new batteries is refunded when a new battery is bought and the used one returned to the retailer;

(b) Germany - a levy of 10 € on all LAB purchased without the return of an old battery.

(c) Canada - Some retailers charge a CAD 5 subsidy on the price of a new lead-acid battery if an old battery is not being returned;

(d) British Columbia: there is an incentive program to encourage consumers living in remote areas to return their used lead-acid batteries, with the subsidy paid varying with the distance traveled and the current price of lead;

(e) Italy: consumers pay an additional charge of €10 when buying a new lead-acid battery. This fee is refunded by the battery manufacturer to an association (e.g., COBAT) which is responsible for collecting WLAB and ensuring that battery recycling is carried out at a licensed plant;

(f) Sweden: battery producers and importers are charged an environmental levy for every battery. This levy covers the cost of battery collection, transportation and recycling and the cost of a public information and awareness programme;

(g) Ghana: the Government has recently imposed a significant levy on the price of new lead-acid batteries and this levy can only be reclaimed by licensed WLAB recyclers. The levy is high enough to provide the licensed recyclers a financial advantage over the informal sector because the informal sector cannot reclaim the levy. This financial instrument effectively keeps the informal sector out of lead battery recycling;

(h) Turkey: In December 2019, the Government of Turkey enacted legislation requiring companies to pay a levy called the "Recycling Contribution Fee" (GEKAP)[34]. GEKAP applies to goods that are potentially harmful to the environment, such as LAB, if they are not recycled correctly.

~~113.~~127. Recycling contribution fees for returned WLAB can be offset from the total recycling contribution liability paid. If the amount to be offset is greater than the recycling fee payable, the excess portion will be carried over, as a credit, to the following financial period. This system provides incentives for responsible LAB manufacturers to maximise the collection and environmentally sound recycling rates for WLAB.

~~114.~~128. An analysis of the costs and impacts of battery collection and recycling for all battery types, including automotive lead acid batteries was produced in 2018 by the European Union[35], entitled, "Study in support of evaluation of the Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators". Essentially, the report did not provide an encouraging perspective for portable batteries, but WLAB were being collected and recycled at above target levels.

### (c) Purchase Discount Schemes

~~115.~~129. Purchase discount schemes operate in a comparable way to the Deposit/Refund systems, but instead of the consumer paying a deposit the first time a LAB is purchased, the consumer will only pay the retail price. However, when the battery needs replacing and it is returned to the retailer, a discount will be given on the price of a replacement battery and the WLAB will be retained by the retailer for collection by a licensed collector/recycler.

~~116.~~130. These systems are invariably run by the collection companies, secondary recyclers or battery manufacturers. The industry bears the costs and sets up the necessary infrastructure to make the scheme work, but the costs are such that the systems are really only viable in countries with domestic recyclers and battery manufacturers. Such schemes are in operation in various countries and regions, for example Europe. In other places, for example, the Philippines, a key battery manufacturer has teamed up with the major licensed secondary lead plant to operate such a scheme throughout its 300 retail outlets.

~~117.~~131. The schemes that are initiated and managed by the battery industry are an example of the "Extended Producer Responsibility" (EPR) principle. EPR is a philosophy where producers have to

[34] https://www.pwc.com.tr/en/hizmetlerimiz/vergi/bultenler/2020/going-green-recycling-contribution-fees-start-in-2020.html.

[35] https://ec.europa.eu/environment/waste/pdf/Published%20Supporting%20Study%20Evaluation.pdf.

take responsibility for the environmental management of their products over the life cycle of the battery.

118.132. Purchase discount schemes are the standard for commercial and industrial batteries and is the reason that lead-acid batteries used for motive power and lifting equipment are all recovered.

(d) **Municipal Waste ~~Recycling Facilities~~Collection Systems**

119.133. Many industrialised countries provide temporary storage facilities, often free of charge, for members of the local community to bring their waste, such as WLAB, to them for disposal/recycling as there may be no places nearby who can collect and store them. In addition, small businesses can also use these facilities but they may incur a small charge. Often these facilities store~~collect~~ batteries for recycling and have designated containers for different types of batteries, including WLAB. The facility may have a contract with a battery collection company to provide plastic bins, which they come and collect, for storing the lead-acid batteries. The collection company will generally pay the municipality a small fee for providing the service given they will be collecting a commodity that can be sold on to a recycling company.

(e) **Local Collection Systems**

120.134. Whilst the most efficient method of collecting WLAB is through the battery retailers using deposit/discount or purchase discount systems, some countries without a national electricity grid will find that the widespread use of LAB is for domestic purposes, such as providing electrical power for lighting and TV, radio, etc. Such remote uses tend to make it difficult for the above collection schemes.

121.135. In remote areas, the battery retailer may be some distance away, which reduces the likelihood that the consumer will want to return the WLAB. However, in low and middle-income countries, individual salvagers/recyclers will often collect discarded materials that can be reused or recycled or sold within the local community. They will call at garages, repair shops and breaker's yards for a WLAB so that they might collect it with the prospect of a payment from a trader or recycler. The salvagers will visit waste sites, strip abandoned vehicles and wrecks and, they will collect WLAB that have been used for domestic standby power and take them to a retailer or collection point. In some instances, the salvager will pay the householder to take away the battery, because it has a resale scrap value. These salvagers are very efficient at finding and collecting WLAB, especially in remote locations.

5. **Packaging and labelling**

122.136. WLAB being transported from the collection points to the recycling facilities should be properly packaged and labelled. Packaging and labelling for transport are often controlled by national hazardous waste or dangerous goods transportation legislation, often based on international standards. If such legislation is lacking or does not provide sufficient guidance, care should be taken to use labels that are in line with the United Nations *Globally Harmonized System of Classification and Labelling of Chemicals*. IATA, IMO and UNECE should be consulted. International standards for the proper packaging, labelling and identification of wastes have been developed, including the following reference materials:

(a) United Nations, 2019b. *Globally Harmonized System of Classification and Labelling of Chemicals*[36] (revised and improved every two years); and

(b) OECD, 2001b. *Harmonised Integrated Classification System for Human Health and Environmental Hazards of Chemical Substances and Mixtures*[37].

123.137. Given the different types of WLAB they should be sized and sorted by type. If they are being palletized, they should be placed in rows that are even so that the pallets are stacked safely in layers. Between each layer there should be cardboard to absorb any potential leakage and minimise the risk of battery shorting. Plastic film and heavy-duty straps can be used to secure the batteries to the pallet in preparation for transportation.

124.138. Preferably UN 2794 approved leakproof plastic WLAB containers should be used to place the collected batteries in them. These containers are designed to be lifted by forklift trucks and avoid the need to handle the batteries, by hand, any further after collection. It also makes it safer and easier to handle and manage at the recycling plant.

[36] https://unece.org/transport/standards/transport/dangerous-goods/ghs-rev9-2021.

[37] https://www.oecd-ilibrary.org/environment/harmonised-integrated-classification-system-for-human-health-and-environmental-hazards-of-chemical-substances-and-mixtures_9789264078475-en.

**Commented [CV22]:** On behalf of the consultant: Municipal facilities provide a valuable system for members of the public to take their WLAB to them - for example car batteries, golf cart batteries which may have been purchased over the internet and there is no local retailer who will take them back. Such systems provide a way to capture WLAB that may otherwise be difficult to enter the recycling network.

**Commented [BRS23]:** SIWG to consider adding information on storage of WLAB, best practices and mgmt of leaking.

**Commented [BRS24]:** SIWG to consider adding guidance on specific details on this waste stream.

SIWG to reconsider mentioning of GHS here as it does not cover waste. Assess whether UN codes could be used instead.

### 6. Transportation

~~125.~~139. WLAB are considered a hazardous waste when being transported. One of the main problems with these batteries is the potential for leakage of electrolyte from damaged or cracked batteries. Waste batteries should be transported ~~complete~~ whole inside containers or palletised in a manner that minimises movement and the risk of electrolyte leakage. WLAB should be stacked upright and evenly to avoid damage and electrolyte leakage. The bins and pallets should be secured to prevent movement with straps on the truck floor, side panels or side bars will assist retaining the load.

~~126.~~140. Shipping containers should be well packed for transport. Plastic WLAB bins inside the container should not be allowed to move while being transported. Therefore, they need to be chocked to avoid this problem.

~~127.~~141. Personal protection equipment, spill kits and other emergency equipment necessary to combat any simple spillage or leakage problems should be provided and the transport team trained in its use and the emergency procedures to follow.

~~128.~~142. Prior to transportation, contingency plans should be documented to minimize environmental impacts associated with spills, fires and other potential emergencies. The shipping documents should include an emergency response telephone number and a certificate that the shipment is in compliance with the regulations. In addition, the shipper should mark the containers with appropriate signs, including the specified label, the proper shipping name and, when the containers contain hazardous wastes, the UN number. For WLAB, the proper shipping name is "Waste lead-acid batteries," and the UN number is "UN 2794" (QSC, 2003). During transportation, WLAB should be identified, packaged and transported in accordance with the following: (a) *United Nations Recommendations on the Transport of Dangerous Goods: Model Regulations* (United Nations, 2021)[38]; and (b) *International Maritime Dangerous Goods Code* (IMO, 2018)[39].

~~129.~~143. Companies transporting hazardous wastes within their own countries should be certified as carriers of hazardous materials and wastes, and their personnel should be qualified and trained in accordance with applicable national and local requirements.

### 7. Storage

#### (a) Collection facilities

> **Commented [CV25]:** On behalf of the consultant: The requirements for small collection facilities such as garages, retailers are significantly different to those of the recycling plants - for example retailers and garages are best using plastic bins as described.

~~130.~~144. All batteries entering a collection/storage facility should be checked to ensure that they are not damaged or leaking. The batteries should preferably be stored plastic acid-resistant bins that may simply be sealed and used as the transport container as well minimizing the risk of an accidental spillage. Those batteries leaking electrolyte, should be stored inside acid resistant containers to minimise risks to the environment and health in a designated storage area. WLAB presented at the collection locations should not be drained of electrolyte since it may pose a risk to human health and the environment as it contains acid and lead.

~~131.~~145. The storage area should be sheltered from rain and weather, stored away from direct heat sources, and where appropriate be bunded and the ground protected with acid resistant concrete or any other acid-resistant material. WLAB stored outside should be in weatherproof plastic containers with lids and placed on impermeable ground. Enclosed areas should be well ventilated with restricted access and be identified as a hazardous materials storage area. Spill clean-up kits and any other appropriate personal protective safety kit should be available to deal with any spills/incidents.

~~132.~~146. The number of WLAB stored at the collection facility will depend on the volume handled by ~~trade rate of~~ the establishment and the capacity of the storage area ~~designed to meet the demands~~. Ideally batteries should be collected on a regular basis to avoid the need to store large quantities of WLAB.

#### (b) Recycling Plants

> **Commented [CV26]:** On behalf of the consultant: The storage facilities at recycling plants are significantly different to those at a retailer or garage for example.

~~133.~~147. WLAB recycling plants may store up to several thousands of tonnes of batteries. On arrival they should be checked to identify the different types of batteries present, e.g. those in steel cases, and for the presence of lithium batteries given these can cause fires and explosions in the plant. Although lithium batteries should have been removed at the collection stage there is always a risk that some have been missed. The different types of batteries can then be segregated and stored in allocated areas before recycling.

[38] https://unece.org/transport/publications/recommendations-transport-dangerous-goods-model-regulations-rev22.

[39] https://www.imo.org/en/OurWork/Safety/Pages/DangerousGoods-default.aspx.

134.148. The batteries should be stored in a designated area in plastic bins/storage containers or on the floor of a covered bay from where they can be scooped up and placed in the battery breaker. The bay should be constructed of an acid-resistant concrete and impermeable floor with a drainage collection system for the electrolyte. This should comprise a sump/drain for the electrolyte so that it can either be treated in an effluent plant or recovered via an acid electrolyte treatment plant for conversion into saleable products such as gypsum. The batteries should not be stored on bare ground to prevent lead and acid contaminating soil and groundwater.

135.149. The covered storage area should have closing doors to minimize the release of lead emissions outside the building. Ideally the area should be under negative pressure and the air extracted via the plant emissions filtration system, details on the types of systems used are specified in the (Best Available Technology Reference Notes) BREF Notes – [reference to be inserted].

136.150. Also included in the storage area should be a firefighting system and safety showers and other emergency equipment and clothing available for personnel in the event of an incident or fire.

137.151. Only authorized personnel should be allowed to enter the WLAB storage area.

## G. Environmentally sound WALB disposal/recycling

### 1. Lead recycling plant planning

138. Many countries have a requirement for environmental impact assessments (EIA) to be undertaken to establish the likely environmental effects of new projects such as hazardous waste recycling plants, lead-acid battery manufacturing plant and modifications to existing operations. The EU, for example, has a Directive (Directive 2011/92/EU)[40] setting out its requirements for undertaking an EIA and what is be covered. The authorities require the companies who are planning to operate the plant or make the modifications to undertake the EIA themselves and submit it to the authorities for review and assessment prior to obtaining approval for a licence setting out the conditions of operation and compliance requirements.

139. Guidance on the requirements for an EIA to be conducted are usually published including guidance on screening and the detailed requirements of what should be covered and included in an EIA report. An example of screening procedure booklet is one produced by the UK Environment Agency[41].

140. The UK, for example, requires a screening exercise to be undertaken to address size, cumulation with other developments, use of natural resources, production of waste, pollution and nuisances, risk of accidents and locations (e.g. wetlands, coastal zones, forest areas, nature reserves and parks, special environmentally designated areas, where environmental quality standards are exceeded and landscapes of historical, cultural or architectural importance) to determine which projects require an EIA. Also, the characteristics of the impact need to be considered (e.g., trans-boundary, magnitude, complexity and probability).

141. Site selection for any new WLAB recycling plant is important to minimize environmental, health and safety risks. It is important to assess potential emissions impacts to the areas around the plant for example, aquifers, groundwater, surface water, farmland, residential areas, businesses, and facilities such as hospitals, schools and processing plants (e.g., food manufacturers). Consideration of factors such as climate, seismic activity, and topography should also be taken into account to assess potential risks from earthquakes, eruptions, flooding, landslides, rock falls, avalanches, and tidal surges. As part of the planning process there is a need to take into account the availability of energy sources, water, emergency services, road links, etc.

142. For existing plants it is important that future residential and commercial developments do not encroach on the plant to avoid environmental, health and safety risks. In addition, it would be advisable to regularly review compliance with best practice in relation to their siting and location and review monitoring data to assess whether any engineering improvements/mitigating measures can be adopted to minimise any potential impacts.

### 2. Access to information & public engagement

143. In many jurisdictions the public have access to and can participate in the process for granting/changing/updating permits/approvals. The authorities are required to make available to the public (including via the Internet) the basis of the decisions, results of consultations, details of the permit conditions, any derogations and the reasons for it, and measures taken by an operator following

[40] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011L0092.

[41] https://www.gov.uk/guidance/environmental-impact-assessment.



**Commented [CV27]:** On behalf of the consultant: General Considerations can be added covering recycling, energy recovery, metals, and metals recycling

**Commented [CV28]:** On behalf of the consultant: The use of the term disposal in the case of WLAB should be considered inappropriate as the dictionary meaning means to get rid of. Given we are talking about the ESM of WLAB recycling is the only ESM. I would recommend that we continue to use recycling in the heading. Perhaps the heading should be ES disposal/recycling - the TOC provided for the development of the ESM of WLAB was ESM recycling.

**Commented [CV29]:** On behalf of the consultant: General Considerations - section to be included to cover recycling, energy recovery, metals and metals recycling, providing guidance and links to TG R4, incineration and landfilling (D5, D10)

**Commented [BRS30]:** SIWG to look into linkages of other adopted guidelines with the view to avoid duplication and ensure consistency.

**Commented [BRS31]:** SIWG to consider revising information on the management of the acid, instead of having information spread in all sub-sections. Possibly adding a dedicated section on it.

SIWG to consider adding information on the mgmt of lead as the output of a recycling process.)

SIWG to review the use of adopted terminology, and add the convention codes when mentioning the mgmt operations.

SIWG to check or add references on specifications mentioned in the document.

permanent cessation of activities. The public also have access to the legal system or another independent/impartial body for a legal review to challenge decisions/acts/omissions. Prior to any legal action being taken the authorities may have a review process/procedure.

### 1. General considerations

152. According to the waste management hierarchy, prevention, minimization, reuse and recycling should be prioritized over other recovery operations and final disposal operations. For pursuing recycling and recovery of plastic and metal wastes, the guidance to assist parties in developing efficient strategies for achieving recycling and recovery of hazardous wastes and other wastes (UNEP, 2019c) may be useful.

153. Disposal operations relevant to WLAB and unrecoverable wastes from the processing and recycling of them and provided in Annex IV, part A and B of the Basel Convention are the following, ordered according to the waste management hierarchy:

(a) Recycling / reclamation of metals and metal compounds (see the *Technical guidelines on the environmentally sound recycling/reclamation of metals and metal compounds*);& recovery operations

(b) Specially engineered landfill (see the *Technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill* (D5));

(c) Incineration on land (see the *Technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1*).

### 1.2. Recycling & recovery operations

144.154. There are three key stages in the recycling/recovery process, these are:

(a) Battery breaking;

(b) Smelting or electrowinning;

(c) Refining.

145.155. The recycling operations also include the informal sector which comprises battery reconditioners and backyard breakers, melters and smelters. In developing countries and those in economic transition they deal with between 15%- 30% WLAB generated. Any environmental and health issues that arise from the informal sector are associated with the low lead recovery rate, acid releases, wastes and emissions[42].

146.156. Informal smelters are only able to achieve about 40% lead recovery for the melting operations and 90% recovery for the smelters. The rest of the lead (~60% for the melters) is released into the environment through the waste and emissions. As a consequence, there is a significant potential for impacts to human health and the environment. In addition, any lead not recovered represents a significant financial loss to those undertaking the recycling.

147.157. Where there is a prominent informal sector the environmental and health risks due to lead pollution are likely to be high. In addition, the domestic supply- demand gap for domestic battery production will be impacted.

148.158. There are several measures that could be undertaken to address both the environmental and health impacts together with improving resource recovery. These include short-term measures aimed at bringing about significant reductions in lead pollution and long-term measures bring about changes in the recycling activities to benefit the local communities.

149.159. The short-term measures to improve the occupational and environmental performance of partial lead recovery activities in the informal sector should include:

(a) Preventing the unauthorized disposal of battery electrolyte through effective legislation and enforcement;

(b) Educating and encouraging owners to ensure workers follow simple safety measures, such as wearing neoprene acid resistant gloves, body aprons, boots, eye protection, and facemasks. The owners should provide washing facilities, a regime of hand washing before eating or drinking and prohibiting smoking in the workplace;

(c) Legislate so that formal recyclers are not allowed to WLAB from the informal sector.

**Commented [CV32]:** On behalf of the consultant: The industry does not regard this as pre-treatment - this is just one of the steps in the recycling process.

**Commented [BRS33]:** SIWG to look at this sentence and fix it. The meaning is not clear and it seems that a verb is missing before WLAB.

[42] https://apps.who.int/iris/bitstream/handle/10665/259447/9789241512855-eng.pdf.

~~150.~~160. Although there are a number of short-term measures that can be introduced the key to bringing about a sustained improvement is the move to the long term solution of an environmentally sound management of waste lead-acid battery recycling. This could be achieved by ensuring that the formal sector only purchase whole lead-acid batteries, banning the export of lead-acid battery components, the introduction of an effective collection scheme and the provision of employment opportunities and training for those engaged in the informal sector.

### ~~3.~~1. Battery breaking

**Commented [CV34]:** On behalf of the consultant: It is better to use this term rather than pre-treatment - this is one step in the treatment process.

#### (a) Process overview

~~151.~~161. The modern battery breaking and recycling process (figure 1) starts with the arrival of used batteries at the recycling facility. It is important to inspect the feedstock to ensure that lithium-ion batteries do not enter the breaker, because if they do, there is a distinct possibility that the battery will explode. Human contact is usually minimized as much as possible, so the batteries are received and directed to the breaking plant by means of automatic conveyors or front-end loaders/forklift trucks.

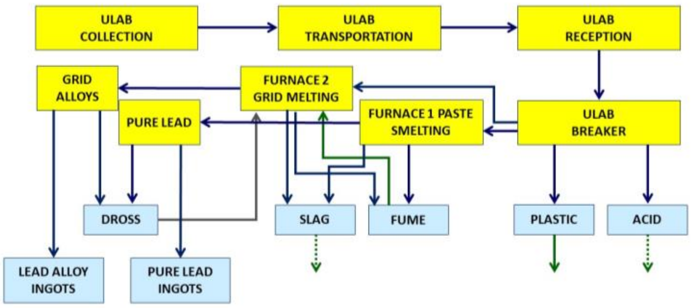



*Figure 1: modern battery breaking and recycling processes.*

**Commented [BRS35]:** SIWG to consider reviewing this figure.

~~152.~~162. Once the waste batteries are loaded into the breaker, they are broken down by a hammer mill. This ensures that all components, such as lead plates, connectors, plastic boxes, paste and acid electrolyte are easily separated in the subsequent hydrometallurgical gravitational separation process.

~~153.~~163. Alternatively, the drained batteries are fed into a ventilated battery saw (OSHA Approved) to remove the top of the battery. The plates are then removed in a rotating drum and set aside to be charged to the furnace in a manner similar to the materials from the hammer mill. Lead terminals are removed from the top of the battery either mechanically or manually and can be charged directly to the refining kettles or the bullion casting pots if no refining is required.

~~154.~~164. After breaking, the lead oxides and sulphates are separated from the other materials by a hydro-gravitational system in water and then by slow moving mesh conveyers. Following separation and drying (vacuum drying in certain desulphurization processes), the paste is charged directed to the furnace, in the case of pyrometallurgical techniques, or for other processes, for example hydrometallurgical techniques to the solvent tanks for digestion.

~~155.~~165. In the case of plates recovered from the battery saw the metallic parts, including lead plates, grids, connectors and terminals, are then placed in a suitable container in preparation for furnace charging or the solvent tanks for hydrometallurgical processing.

~~156.~~166. The hydro-gravitational processes, through use of the density properties of the WLAB components and hydraulic pumped mechanisms, separates the broken battery component pieces into three discrete fractions: the first one is the light fraction such as the plastics, that is, the case material and the separators, the second is the fine slurry of lead oxides and sulphates and the third is the heavy layer consisting of lead grid metallics from the battery plates, the lead connectors, and the terminal posts. The plastics recovered in this process are washed and rinsed, often in the final stage in alkaline solution, to remove any traces of lead oxides and sulphates. In the most modern breakers, the separators are also segregated and discharged from the breaker to be charged to the furnace because they cannot be recycled.

~~157.~~167. After these separation steps, the organic layer is further separated into polypropylene or ABS waste streams (organics), and separators that can contain some organics and sometimes minerals, such as silica and more often a mixture of both. Unless the breaking system is connected to a plastics recycling process, the plastic chips are bagged and stored ready for dispatch to a suitable plastics recycler. The separators, whether polyester or glass matte can be charged to the furnace for disposal.

~~158.~~168. Depending on the process battery electrolyte can be separated prior to breaking or during breaking, but whichever process the treatment for the disposal or reuse of the electrolyte is the same.

~~159.~~169. Battery electrolyte can be recovered, reconditioned, and returned to battery manufacturers to fill new batteries. Only a few recycling plants can do this and investment in the equipment can be expensive to make recovery and reconditioning viable.

~~160.~~170. Alternatively, in hot climates it is possible to contain the electrolyte in a shallow lagoon or pond and allow the liquid to evaporate. In some countries it is necessary to install a polycarbonate roof to ensure that the lagoon does not spill over the sides in the rainy season, and a polycarbonate roof also accelerates the rate of evaporation.

~~161.~~171. If it is necessary to discharge the effluent after treatment, the acid waste stream will need to be neutralized, as follows:
three examples:

(a) Adding sodium hydroxide to the electrolyte to produce sodium sulphate and water, and in a similar manner, sodium carbonate can be added to also produce sodium sulphate and water, but this process will also liberate carbon dioxide. S*odium sulphate* is used in the manufacture of glass, soaps, and detergents, but purification involves vacuum distillation and the equipment is expensive and not necessarily suitable for an SME;

(b) Adding lime or calcium hydroxide to precipitate calcium sulphate, i.e., gypsum. This is a saleable product and can be sold to the cement industry and used for wall boarding;

(c) Adding ammonium carbonate with lead paste so that it reacts with the lead sulphate to form lead carbonate and ammonium sulphate, a rich source of nitrogen.

~~162.~~172. Battery breaking methods differ from one another in process details and evolve as new technology becomes available. The suitability of each one for a given lead recovery plant depends on several specific factors such as local economy, quantity of raw materials as well as the demands of the smelting facility. If mechanical battery breaking equipment is unavailable, for whatever reason, the safest approach to prepare the battery for smelting would be the following: puncture and drain the electrolyte for the battery and treat it accordingly; remove the top of the battery complete with plates and separators using an approved battery saw under strict health, safety and environmental controls.

**(b) Environmental ~~Potential sources of environmental~~ contamination sources**

~~163.~~173. This section, and the other two sections on lead reduction and lead refining, are not designed to describe or extensively list all possible sources of contamination or occupational exposure that may occur in the lead recovery processes, as changing and evolving technologies and processes will present new risks and threats. It is designed, instead, to itemize a short predictable list of common contamination sources. Specific sources of contamination will have to be determined in the light of the process employed. The common sources of environmental impacts and risks in battery breaking are:

(a) Battery acid spillage - acid electrolyte and lead contamination source: battery spillage can be a common source of environmental contamination and potential human health impact since the electrolyte is not only a strong corrosive solution, but also a good carrier of soluble lead and lead particulates. Therefore, if this spills in an unprotected area, it may contaminate the soil or injure workers. If there are spills on unprotected soil, the soil itself becomes a source of lead dust once the solution evaporates and the lead becomes incorporated into soil particles which may be blown and made airborne by the wind or raised as dust by vehicle movements;

(b) Manual battery breaking – source of human health risks and environment damage through heavy spillage and lead contaminated dust formation: manual breaking usually relies on primitive tools, inadequately protected workers and little or no environmental protection measures. The situation is even worse in the case of sealed batteries, which are not easily drained, increasing dramatically the risk of damage to human health when the plates are removed from the case by hand. Therefore, manual battery breaking should be avoided in all circumstances;

(c) Mechanical battery breaking – source of lead particulates and acid mist from the hammer mill: the process of breaking batteries through breaking in a hammer mill may spread lead particulates and acid mist unless the breaker is housed in a ventilated and sealed building. However, the fact that the mill is sealed and uses copious quantities of water and battery electrolyte usually means the formation of such particulates is prevented, but there is a dust emission risk if drained and dry WLAB are processed in a hammer mill. It is also worth noting that mechanical breakers are very noisy and should be sound proofed to reduce the noise level below the legal limit. In the case of older breakers, where installing sound proofing may not be possible, ear defenders should be worn.

(d) Hydraulic separations – contaminated effluent leakage: the hydraulic separations, both metallic from organic and heavy organics from light organics, are usually preformed inside sealed plant and with a closed effluent system. However, if any effluent leakage occurs, it will be acidic and heavily contaminated by lead compounds;

(e) Plastic and chips – contaminated wastes: plastic chips produced in the mechanical breaking will pose a problem unless they are washed thoroughly to remove traces of lead oxides and sulphates. Therefore, it is important that the final traces of lead are removed by a second wash, preferably in an alkaline solution, followed by another rinse in clean water prior to further treatment.

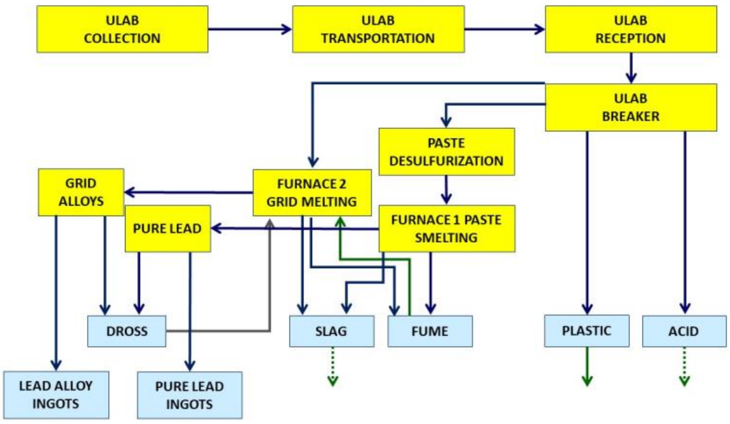
## ~~4.~~2. Lead reduction

~~164.~~174. The battery scrap obtained from the breaking process is a mixture of several materials: metallic lead, lead oxides (PbO and PbO2), lead sulphate (PbSO4) and other metals such as calcium (Ca), copper (Cu), antimony (Sb), arsenic (As), tin (Sn) and increasingly, silver (Ag). In order to isolate the metallic lead from this mixture, two methods may be applied: pyrometallurgical processes, also known as fusion-reduction methods, and hydro-metallurgical processes, or electrolytic methods. It is also possible to combine the two and use a hybrid process.

### (a) Pyrometallurgical methods

~~165.~~175. The object of the pyrometallurgical processes, or fusion-reduction methods, is to chemically reduce all metallic compounds to their metallic, or reduced, forms by means of heating and providing adequate fluxing and reducing conditions, compounds or elements (figure 2).

Commented [BRS36]: SIWG to consider revising this Figure. Missing caption below the figure.




~~166.~~176. Prior to smelting, some methods may be employed to de-sulphurise the lead sulphates in the battery paste by reacting it with a mixture of sodium carbonate ($Na_2CO_3$) and sodium hydroxide (NaOH), such as in the Engitec CX and related processes, converting the lead sulphate ($PbSO^4$) to lead oxide (PbO). Sometimes the desulphurizing agent may also be iron oxide ($Fe_2O_3$) and lime ($CaCO_3$). These procedures reduce the amount of slag formed during smelting and also, depending on the smelting method, the amount of sulphur dioxide ($SO_2$) released and therefore reduces the sulphur dioxide containment and capture problems. However, other methods simply add controlled amounts of scrap iron directly to the furnace in order to capture the sulphur, which will then be referred to and contained in the slag. This process does, however, increase the amount of slag produced.

~~167.~~177. The acid electrolyte should also be treated to extract the dissolved lead content so that it can also be sent to the smelting furnace. This is carried out by neutralization of the electrolyte solution with sodium hydroxide, which precipitates the lead as lead hydroxide [$Pb(OH)^2$]. This compound is then removed by decantation or filtration and directed to the furnace. The remaining solution, sodium sulphate diluted in water ($Na_2SO_4$), may be further purified and the salt isolated in high purity grades (up to food grade quality), such as in the CX Engitec Impianti process. Alternatively, other products can be produced from the electrolyte as already discussed above.

~~168.~~178. The most energy efficient operation is to charge the metallic fraction to a melting furnace and the lead compounds derived from the de-sulfurization and neutralization processes to a smelting furnace with fluxing and reducing agents. The heat can be provided by a variety of sources depending on the specific fuel or mix employed, such as oil, used oil, gas, natural or bio-gas and a fuel enrichment burner using oxygen under controlled conditions etc. There are also several different furnace designs in which the smelting process may be carried out: rotatory furnace, reverberatory furnace and blast or electric furnace, bottom blown furnaces and so on. The best technology to employ will depend upon several factors that include local economics, the planned or projected amount of recycling, and so specific information may be found in the references provided at the end of these guidelines. It should also be noted that certain furnace technologies that facilitate the use of oxy-fuel burners can reduce nitrogen oxide emissions.

~~169.~~179. The fluxing agents, which enable the mix of materials in the furnace to “melt” at a temperature below the lead compounds melting temperature, are added not only to reduce the lead smelting temperature, but also to provide a liquid solvent, which traps several unwanted compounds and impurities during the smelting and reducing processes. As the flux starts to be contaminated with all sorts of impurities from the smelting process the formation of the slag also starts. The physical and chemical properties of this slag, which are important characteristics to be considered in a later treatment, are entirely dependent on the chemical composition of the flux that is used.

~~170.~~180. Reducing agents, on the other hand, are added with the purpose of reducing the lead oxide (PbO) and hydroxide ($Pb(OH)_2$) to metallic lead. It is usually a carbon-based compound such as coke, coal fines or other natural carbon sources.

~~171.~~181. The quantity of flux and reducing agent added should be carefully controlled:

(a) An insufficient amount of flux will not enable all the sulphur and other materials present in the charge material to be controlled and a greater quantity of sulphur dioxide may be released to the atmosphere;

(b) An insufficient amount of reducing agent, on the other hand, will not reduce all lead oxides and sulphates present in the scrap and the slag will be heavily contaminated with lead, which may be a potential source of an environmental hazard.

~~172.~~182. After the process has reduced all the leaded compounds, the molten metallic lead will accumulate at the bottom of the furnace. However if the material in the furnace is derived from the grid metallics, it will contain other metals of economic value. Therefore, this lead bullion should undergo a refining process before pure lead (99.97% to 99.99% purity) can be recovered from it. Alternatively, it can be partially refined to produce an alloy.

**(b) Hydrometallurgical methods**

~~173.~~183. Hydrometallurgy shows significant advantages as an environmentally friendly process in comparison with pyrometallurgy: low-temperature of operation and low emissions of hazardous gases.

~~174.~~184. In recent years, a number of hydrometallurgical processes for recovery of lead from WLAB were developed in order to reduce environmental impact and operating costs compared to traditional lead recycling. While these technologies are at different phases of maturity, all are facing similar challenges: purity of the recovered products, energy efficiency, resources consumption, waste remediation.

~~175.~~185. All hydrometallurgical processes begin with a breaking phase, but in the case of hydrometallurgical recycling the only option is mechanical breaking using a hammer mill, because the grid metallics should be separated from the battery paste so that the two lead bearing components can be recycled separately.

~~176.~~186. It is entirely possible dissolve the grid metallics in a suitable solvent and then recover the lead using an appropriate electrolytic process or melt the grid metallics in a suitable furnace and refine the lead as required.

~~177.~~187. The better the separation of the grid metallics and the battery paste, the more efficient and effective will be the hydrometallurgical treatment of the paste.

~~178.~~188. Typically, hydrometallurgical methods comprise a leaching step, followed by electrowinning or calcination to produce metallic lead (Pb), lead oxides (PbO) or lead oxides (Pb/PbO).

**(i) Leaching followed by electrowinning**

~~179.~~189. The objective of electrolytic processes is to electrically and selectively reduce all lead compounds to metallic lead.

~~180.~~190. In hydrometallurgical electrowinning, lead paste undergoes wet processing, where it is dissolved in a solvent, followed by electroreduction to produce metallic lead, typically at ambient temperatures. These deposits can be obtained in high purity, thus eliminating the need for lead refining.

~~181.~~191. The chemical concept behind the electrolytic process is the conversion of all lead compounds into a single chemical species, lead in an oxidation state +II (Pb2+ or plumbous lead) in this case, which is then electrochemically reduced to produce metallic lead.

~~182.~~192. Examples of electrowinning processes include: PLACID, FAST® and FLUBOR®. These are based on different sets of leaching reagents, desulphurisation or reducing agents, electrolyte systems, electrochemical cell design or an order of process steps.

**(ii) PLACID process**

~~183.~~193. In the PLACID process[43] (Fig 3) acidic aqueous brines are used as leaching reagents to produce lead chloride solution from spent lead paste. Sulphates are removed from the system by adding lime to create gypsum, whereas metallic impurities (Bi, Cu, As, Sb) are cemented using lead powder. The purified lead chloride solution is electrolysed to produce high-purity lead product (>99.99%) with a recovery efficiency of 99.5%.

~~184.~~194. The electrolysis deposits lead as dendrites or spongy lead, which are subsequently shaken off and collected on a conveyor belt and pressed to form platelets of pure lead (99.99%), which can then be conveyed to a melting kettle for casting into ingots, while acid produced in the electrochemical cell is regenerated and reused in the leaching step. The whole extraction process can be run continuously for 24 hours per day, without interruption provided there is a continuous electrical supply.

~~185.~~195. Although it may be costly sometimes when considered as an isolated plant, this process provides good results when linked to a low temperature smelting plant since, with the appropriate separation of raw materials, it is a technological solution to overcome the lead smelting and refining emission problems.

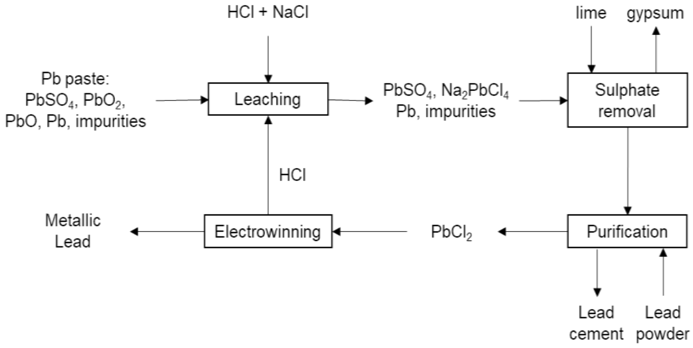



*Figure 3. Diagram of PLACID process*

[43] https://www.osti.gov/biblio/197296.

### (iii) FAST® Pb process

~~186.~~196. The Flakes Auto-Stripping Technology (FAST® Pb Process, Fig. 4)[44] is based on an electrochemical flow-cell with an ammonium chloride electrolyte. The process starts with desulphurisation of spent paste, followed by leaching with ammonium chloride. Hydrogen peroxide is used as a reducing agent. The leachate is purified with lead flakes and fed to electrowinning cell.

~~187.~~197. The electrolysis takes place in a bipolar flow cell. The process conditions and cell geometry are optimised to produce dendritic lead (flakes) that can be sheared and taken out from the cell by the electrolyte flow which passes through the electrodes at a very high linear velocity. The solution (NH4Cl) from the electrolytic process can be reused in the leaching step.

~~188.~~198. Unlike with other electrolytic chloride systems, no chlorine emissions are generated. The stripping process can be run continuously with plating current efficiency of >85%.

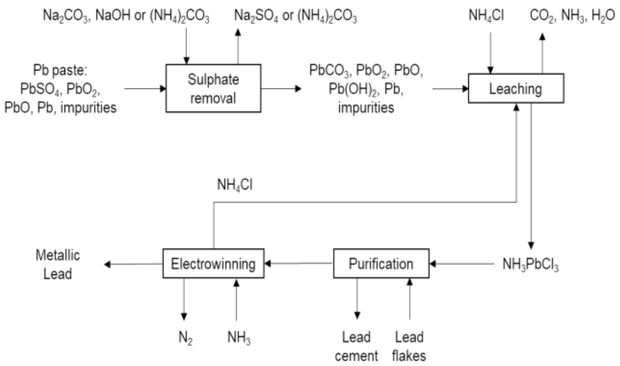



*Figure 4. Diagram of FAST® Pb process*

### (iv) FLUBOR® process

~~189.~~199. The FLUBOR® process[45] is an electrolytic process for lead recovery from lead-acid batteries scrap (paste and metallic grids) and directly from galena. Figure 6 shows a schematic representation of the recycling process from spent lead paste.

~~190.~~200. After sulphidation of spent lead paste, the resulting lead sulphide (PbS) is leached with ferric fluoroborate-fluoroboric acid. The resulting solution of lead fluoroborate undergoes a purification step to remove antimony, arsenic, bismuth, copper and silver before being fed as an electrolyte for electrowinning.

~~191.~~201. The electrochemical system is based on a diaphragm-divided electrowinning cell. Metallic lead is plated at the cathode, whereas ferric ions are produced at the anode with no oxygen emissions. The solution produced in the anode compartment is regenerated and reused in the leaching step (closed loop leach system).

~~192.~~202. The lead extraction rate of the process is >97% and the produced lead cathodes have a lead content of 99.99%.

[44] https://link.springer.com/chapter/10.1007/978-3-030-37070-1_50.

[45] https://www.engitec.com/index.php?a_lang=en&a_name=lead.

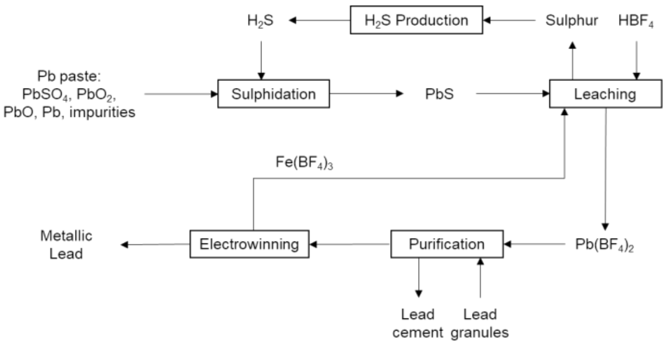



*Figure5. Diagram of FLUBOR® process.*

**(v) Aqua refining process**

~~193.~~203. The Aqua Refining process[46] is using an aqueous solution of methane sulphonic acid (MSA) and ethylene diamine tetra acetic acid (EDTA) to recover metallic lead (see Figure 6.).

~~194.~~204. Desulphurisation of spent lead paste produces sodium sulphate and lead hydroxide. Sodium sulphate can be electrolytically regenerated to sodium hydroxide and sulphuric acid. The former is reused as a desulphurising agent. Desulphurised paste is leached with MSA and EDTA to form a lead complex.

~~195.~~205. Lead is subsequently recovered through the electrolytic reduction. Low-density (<1g/cm3) metal is produced at self-cleaning rotating cathodes, collected continuously and compressed into lead blocks. The Aqua Refining process obtains metallic lead in high-purity (>99.99%) at room temperature and without producing any slag.

**(vi) Leaching followed by calcination**

~~196.~~206. The objective of the process based on leaching and calcination steps is to produce leady oxides that can be directly used as a precursor material for battery paste for new batteries. This approach does not require a conversion from lead ingots (metallic lead) to leady oxides, making the route from WLABs to new LABs shorter in comparison with pyrometallurgical or electrowinning methods.

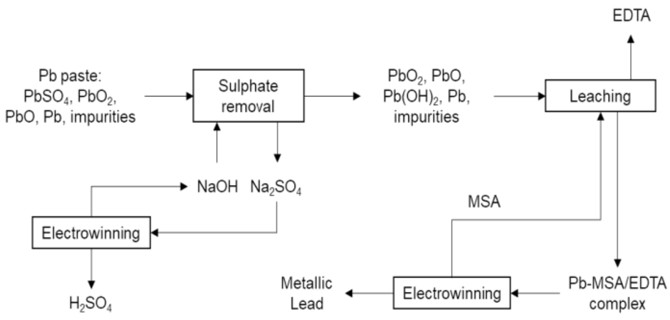



*Figure 6. Diagram of Aqua Refining Process*

[46] https://www.recyclingtoday.com/news/aqua-metals-technology-streamlines-lead-battery-recycling/.

### (vii) FenixPb process

~~197.~~207. FenixPb process produces battery-ready lead oxide directly from lead paste without producing lead ingots (Figure 7.)[47]. Lead paste pre-processing includes desulphurisation step with caustic soda (NaOH) to convert PbSO4 to PbO, followed by a treatment with hydrogen peroxide (H2O2) to reduce PbO2 to PbO.

~~198.~~208. In the next step, lead paste is chemically treated with organic acids to remove trace metal impurities and produce lead citrate precursor. The precursor is then calcined to produce pure nano-crystalline leady oxides (99.99%). This product is composed of PbO and small amounts of metallic Pb. Tuning the calcination conditions, e.g. temperature, atmosphere, regulates the amount of free Pb and the ratio of α:β lead oxides.

~~199.~~209. The process provides a significant reduction in energy consumption and minimal SO2, NOx and CO2 emissions. The estimated slag production is 50-90% lower in comparison to smelting lead -acid batteries.

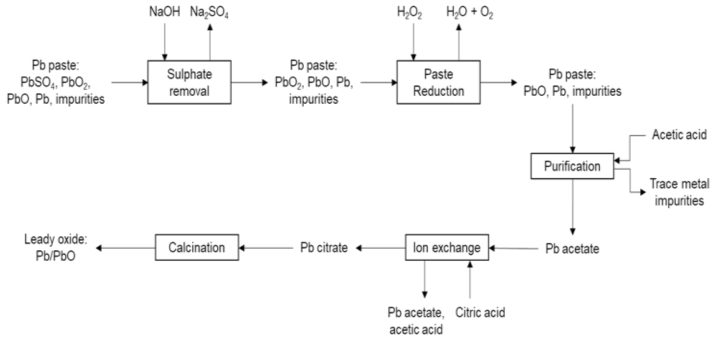



*Figure 7. Diagram of FenixPb process and its production of leady oxides.*

### (viii) Deep Eutectic Solvents

~~200.~~210. All hydrometallurgical processes developed to date rely on the use of water as a liquid medium. However, production of lead oxides and leady oxides via chemical methods can be also achieved from non-aqueous solutions. A novel class of solvents, called deep eutectic solvents (DESs) recently have demonstrated high solubility of lead compounds, while having little associated hazards.

~~201.~~211. Deep eutectic solvents are liquids formed from a eutectic mixture of typically two components, such as ethylene glycol, urea or choline chloride. These chemicals are commercially available, inexpensive, easily to handle and environmentally benign. Importantly, coordinating properties of deep eutectic solvents enable solubility of wide range of lead compounds, including lead oxides - up to 100g/l.

~~202.~~212. Although economics of the process are yet to be established, the use of DES has shown to produce lead oxides directly from lead paste, without the need for a separate desulphurisation step.

### ~~5.~~3. Lead reduction: ~~potential sources of~~ environmental contamination sources

~~203.~~213. The common sources of adverse human health and environmental impacts in the pyrometallurgical lead reduction processes are:

(a) Lead compounds derived from the breaking process – L~~l~~ead and lead compounds in dust and electrolyte; the separated and fine materials from the breaking process are usually wet, since the main processes of separation are based on hydro-gravitational techniques. However, if they are not incorporated in a fully automated process, they will have to be transported from the breaking facility to the reduction facility and some slurry material may spill and fall from the transport system. After drying, these materials become a powder and may contaminate the factory and its surroundings as fine lead dusts. There are also similar problems associated with the processing of drained and dry WLAB because there is a greater

[47] https://www.bestmag.co.uk/eu-grant-boost-uk-lab-recycling-research/.

propensity for dust generation. If it is necessary to process dry WLABs through a mechanical hammer mill, they should be interspersed with whole undrained WLAB so that the risk of dry lead dust generation is reduced;

(b) Drosses – lead contaminated materials: drosses are formed during the refining process and they are produced to remove impurities that are not easily incorporated or wanted in the refined lead. However, these drosses still contain a high percentage of lead that can be recovered and so these by-products are recycled in the pyrometallurgical process by returning them to the furnace. In order to accomplish these tasks, the drosses should be removed and transported to the furnace charging bay, but since they are usually a dusty material and occasionally powdery (copper dross), they may be a source of lead contamination while being transported;

(c) Filter plant (Baghouse)– lead contaminated dusts: furnace ventilation systems, that is, for the combustion gases and hygiene hoods, need to be ventilated to a filter plant to capture lead dusts formed in the pyrometallurgical process. After being used, they are usually recycled in the same smelting process since they may contain as much as 65% of lead. However, the care and maintenance of these filters may be an important source of contaminating dust, which could pose a risk to the human health and the environment. Besides, over-used filters no longer capture lead dusts as originally intended and the dust emissions from the furnace becomes an important source of fugitive contamination. Finally, the furnace inlet is itself a source of lead dust to the environment, since it can be an open system. The high temperature fume that leaves the furnace inlet and tapping area, for example, have a high lead content, and will be readily absorbed by the human body due to its particle size, that is, 0.1 to 0.7 microns;

(d) Sulphur dioxide emissions – the percentage of sulphur from a given amount of lead scrap load that leaves the reduction system as sulphur dioxide is highly dependent not only on the furnace conditions, but also in the kind of slag material being formed. As a general trend, this number may fall between 0% to 10% and it is significantly reduced if the flux used is a mixture of iron and sodium-based compounds producing sodium slags and pyrites. Ebonite also has 6-10% of sulphur that may contribute to the sulphur dioxide emission if it is added to the furnace charge, although this is now rare as ebonite battery case material has been phased out;

(e) Organic material combustion – tar formation: in a well-structured and controlled refinery tar formation or burning embers is not a significant issue since the reduction process consumes all organic materials. On the other hand, in the less controlled process there is a greater is the risk of tar formation and emissions of burning embers from the furnace, especially in artisan foundries. If the reduction furnace has filters, the emission of tars is an even greater problem since they are very pyrogenic and may produce fires in the filtration plant, thus increasing the risk of an accident and the possibility of a rogue emission. The introduction of afterburners to complete the combustion of gases from the furnace is the usual solution to this problem, but a complete restructuring of the process, removal of organics for example, may present better perspectives. Spark arrestors located in the ducting leading to the baghouse will also reduce the risk of burning embers reaching the filter bags;

(f) Chlorine and chlorine compounds emission: an initial separation of the materials, such as PVC separators, allowed to enter the reduction process reduces the chlorine emission considerably. However, increasing amounts of PVC in the furnace increases the chances of chlorine emissions. The major part of it is absorbed by the basic calcium or sodium slags, however some of the chlorine is chemically converted into Lead chloride which is volatile under furnace conditions but captured by dust filters as the temperature decreases. The risks associated with PVC separators has largely diminished due to the introduction of polyester and glass matte separators;

(g) Slag production: the furnace residues or slag makes up most of the waste production during the reduction process. As an average, around 300-350kg of slag is produced for each tonne of metallic lead, depending on specific factors of the process and the kind of residue being formed (calcium or sodium slags), and up to 5% (w/w) of this slag is composed of lead compounds. Therefore, special consideration should be given to the leachate that may be produced if an unstable water-soluble slag encounters water or moist air. A purpose built under cover storage bay to store this material should be planned well in advance to avoid human health and environmental problems associated with the slag as it degrades.

~~204.~~214. Increasingly, smelting operations are contained in an air-conditioned building under negative pressure or encapsulated with ventilation to a baghouse to mitigate the risk of emissions from the furnace operation, particularly during charging and tapping, escaping to atmosphere. It is certainly recommended that smelters should be contained in an enclosed, but ventilated environment and not open to atmosphere.

### ~~6.~~4. Lead refining

~~205.~~215. As indicated earlier, if a smelting plant that is recycling a mix of plates and lead oxide stops at the stage of the furnace-reduction plant, it will produce what is known as hard or antimonial lead. If the plant is meant to produce soft lead, the crude lead bullion it should undergo a refining process. The objective of the refining process is to remove as many of the unwanted impurities as possible including, copper (Cu), antimony (Sb), arsenic (As) and tin (Sn), since the soft lead standard does not allow more than 10g per tonne of these metals.

~~206.~~216. WLAB recycling plants that process the lead grid plates and the lead paste separately through two or more dedicated furnaces or by campaigning the plates and the oxide separately through one furnace, will produce two distinctive lead bullions. The bullion produced from the paste will have very few impurities and should require the minimum of refining to produce pure soft lead at either 99.97% or 99.99% purity. The bullion produced by recycling the plates, normally through a melting operation, will contain certain metals used to produce the grid alloys and other possible metallic impurities. This bullion can be refined to produce pure soft lead, but is better suited to produce grid alloys, and whenever possible retaining the metals in the bullion that make up the grid alloy.

~~207.~~217. There are two methods of lead refining: hydrometallurgical methods, which were already described in the lead reduction section, and pyro-metallurgical or thermal processes, which are described here.

#### (a) Pyrometallurgical Refining

~~208.~~218. Thermal refining is performed in the liquid phase, which means that the crude Lead should be melted to temperatures higher than 327ºC (lead melting point), but less than 650ºC (lead boiling point). As a general trend, the process is performed in batches of 20 to 100 tonnes, according to the refining plant capacity.

~~209.~~219. The chemical concept behind the refining process is the addition of specific reagents to the molten lead at appropriate temperatures. These reagents will then remove the unwanted metals in a specific order as they are added selectively (figure 8).

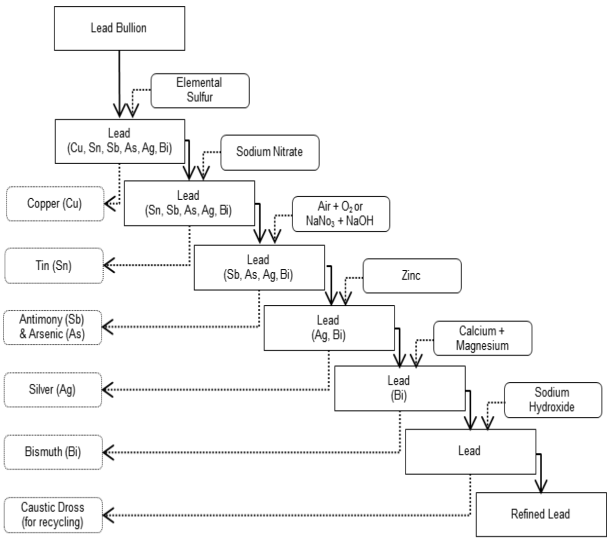



*Figure 8: pyrometallurgical lead refining.*

~~210.~~220. Copper (Cu) is the first element to be removed with elemental sulphur in a two-phase procedure. In the first step, almost all the copper is removed as copper sulphide (CuS) drosses when elemental sulphur is added to the molten lead bath at 450ºC. The second step is meant to remove all remaining copper by adding small amounts of elemental sulphur to the molten lead at 330ºC until no further reaction takes place. As the use of sulphur requires strict health and safety requirements to prevent fires and good ventilation to prevent choking from acrid fumes. A safer alternative is to use iron pyrites thereby eliminating the risk of fire and acrid fumes.

~~211.~~221. The tin is usually removed in the smelting process and only needs removal in the refining stage if scrap lead grids and other solid lead materials have been added to the refining kettle without passing through the furnace and allowed to melt into the molten bath. The tin is so unstable that just stirring the bath and adding some sodium nitrate ($NaNO_3$) is usually sufficient to remove it. If there is still some residual tin it can be removed using an air lance in the kettle.

~~212.~~222. Arsenic (As) and antimony (Sb) are selectively removed by oxidation with either air enriched with oxygen ($O_2$) or a mixture of sodium nitrate ($NaNO_3$) and sodium hydroxide (NaOH). The temperature of the molten lead is raised to 550ºC and a flow of $O_2$ enriched air is bubbled into it. The reaction is extremely exothermic, and the temperature easily reaches 650ºC. Then the resulting drosses are a mixture of oxides (25% Sb, 10% As and 65% Pb).

~~213.~~223. Silver (Ag) comes next, but this stage is normally only applied to primary lead bullion because the quantities in WLAB are too small to remove economically. Its removal is carried out by the Parkes Process, which makes use of the preferential solubility of silver in molten zinc (Zn) instead of molten lead (Pb). Therefore, metallic zinc (Zn) is added to the molten lead at 470ºC and the mix is allowed to cool to 325ºC. A silver lead-zinc alloy separates and forms a crust on the surface. The crust is removed, and the zinc separated from the silver by vacuum distillation. The crude silver is further refined using oxygen to produce fine silver. The excess of zinc is removed from the de-silvered lead by vacuum distillation and then by sodium hydroxide (NaOH).

~~214.~~224. Finally, bismuth (Bi) is removed, if necessary, by treatment of the resulting lead with a mixture of calcium (Ca) and magnesium (Mg), also known as the Kroll-Betterton process. A calcium-magnesium-bismuth alloy is formed as dross on the surface of the molten lead and then removed by skimming. The drosses are oxidized and further refined to produce fine bismuth. This process is not normally applied to ULAB as Bismuth is often one of the beneficial elements added to lead to produce battery alloys and is not usually present in such proportions to cause problems attaining 99.97 or better impurities.

~~215.~~225. The lead is then treated with sodium hydroxide (NaOH) to remove any residual impurities and finally cast into one-tonne blocks or 25 or 40 kilo ingots. Drosses, litharge and other substances formed during the refining process are known as by-products and are returned to the furnace to recover any Lead in the by-products.

### ~~7.~~5. Lead refining: ~~potential sources of~~ environmental contamination sources

~~216.~~226. The refining process can be a polluting process if control measures are not taken. The major sources of environmental impacts in the Lead refining process are:

(a) Overheated lead – lead fumes: sometimes the molten lead tapped from the furnace is introduced directly into the refining kettle, which may be as hot as 1,000ºC or more. Therefore, it is not uncommon that the lead refining process produces large amounts of lead fume and possibly vapour, depending on how quickly the metal cools on impact with the lead in the kettle. Ideally lead should be tapped from the furnace via a refractory lined launder directly into a lead bath or allowed to cool prior to pouring. In any event the refining kettle should be covered and ventilated;

(b) Sulphur dioxide ($SO_2$) emissions: the copper removal by addition of elementary sulphur may produce large quantities of sulphur dioxide ($SO_2$), since sulphur oxidizes readily in the presence of oxygen at the refining temperatures. The use of iron pyrites eliminates this problem;

(c) Dross production and removal – metal contaminations: the dross production and removal from the refining kettle while removing unwanted metals from the unrefined lead may pose threats to human health and environment due to the physical characteristics of the drosses and the dusts generated as the dross is removed. Sometimes they are in the form of a very fine and dry dust, such as the copper dross, with a high percentage of lead and other metals, so it is essential to provide adequate ventilation during dross removal and the dross should be covered or sealed in a suitable container for storage or return to the furnace or transport to another destination for further treatment. The dross should be treated as a potentially hazardous by-product;

(d) Chlorine ($Cl_2$) tin (Sn) removal and recovery – in some older recycling operations tin was removed by chlorine gas, but this process has so many potential health risks that it is not recommended because an uncontrolled accidental release or addition of chlorine may release the poisonous gas into the workplace or the environment. Besides, the storage and handling of chlorine is itself a delicate operation due to its corrosiveness and toxicity;

(e) Oxygen (O2) enriched air tin (Sn) removal – lead fume: while the air or air and oxygen is being passed into the molten metals, the nitrogen (N2) present in the air does not react. The consequence of this is that the gas bubbles violently to the surface of the metals releasing dusts and metallic fume; therefore, this process should be properly ventilated and as the reaction is endothermic temperature should be controlled to prevent overheating.

### 8.6. Polypropylene Plastic recycling

Commented [BRS37]: SIWG to consider adding more information on hazardous waste.

217.227. The recycling/disposal of plastic wastes is covered under the technical guidelines on the environmentally sound management of plastic wastes[48]. A brief summary of the steps involved at battery recycling plants is summarised below. More detailed information can be obtained from the ESM of plastic wastes technical guidance.

218.228. Polypropylene (PP) plastic and acrylonitrile butadiene styrene (ABS) battery case can both be readily separated and collected during the during the hydro separation stage after the breaker. The plastic wastes are a valuable product for automobiles, plastic pipe, drainage and other uses. It represents a good financial income for the recycler. Either the recycling plant will have a PP chip line, or it will need to be sent off site for recycling. The recycling process of involves several phases, which include:

(a) Collection: the plastic chips are generally collected in hoppers or on the floor during the separation of the various waste streams via a mechanical belt sorter. At this stage the PP chip will still be contaminated with residual lead and lead oxide and care is therefore needed during the its handling. If the PP chip is going off site it will need to be either washed further prior to being dispatched to remove the lead residues or sent to a recycler capable of handling lead contaminated plastics. It should not be sold unwashed unless the purchaser can comply with environmentally sound management practices to safeguard environment and health. Further details on the separation process are described in paragraphs [156 and 157];

(b) Cleaning: further cleaning of the PP on site should be carried out before shredding and compounding. Strict quality assurance should be applied to ensure the PP chips are free of lead contamination. Although the process waters from the washing cycles can be reused the final wash should be in clean water;

(c) Shredding: once the plastics have been cleaned they can be shredded and dried prior to;

(d) Compounding: the final phase is compounding where the plastic is recombined using an extruder, which melts down particles at a high temp, creating pellets of the plastic. Then, the pellets or granules are ready to be used by manufacturers to make new lead-acid battery cases or car components.

### 7. Slag wastes

229. Slags are the major hazardous waste formed during the whole process once the battery electrolyte has been removed, contained, and treated. Battery processing slags account for 13%-25% of the weight of lead produced. The method of dealing with slag wastes depends on the leachability of the metals they contain, and this is determined by the fluxes used and the operating conditions. Either calcium carbonate or sodium carbonate is added producing a calcium or soda slag.

230. Adding lime, calcium carbonate ($CaCO_3$), to the furnace produces a non-leachable slag, which is a more environmentally sound furnace residue waste. It increases the temperature of the furnace and produces more sulphur dioxide, resulting in higher energy costs and affecting the life of the refractories. Lime is much easier to deal with than sodium carbonate ($Na_2CO_3$) which produces a leachable slag.

231. Sodium slag tends not have any use due to its physical and chemical properties, and, therefore, it tends to be disposed of as a hazardous waste to a regulated hazardous waste landfill. In some cases, it is possible to reprocess it for cement addition to stabilise the slag for use in paving slabs or building bricks (subject to passing the appropriate building regulations and leachate tests) but this is not yet widespread.

232. Calcium slags can be used as a raw material in cement production in road building, bricks, etc. A calcium-based flux may be considered as a viable option since it provides a stable furnace slag.

233. The key to using slags rather than disposing of them to a specially engineered hazardous waste landfill depends on minimising its leachability and the lowering metal levels. Where this is not currently possible the slags should be disposed of at specially engineered hazardous waste landfills

[48] http://www.basel.int/Implementation/Plasticwaste/Technicalguidelines/Overview/tabid/7992/Default.aspx.

(see technical guidelines on specially engineered landfills that have been developed by UNEP Basel Convention[49]).

### 8. Unrecoverable wastes management

234. In theory it is possible to either recycle and recover or use all the WLAB components in the recycling process in such a manner that there are no waste materials to dispose of, apart from the separators and other materials associated with the production processes such brick furnace linings, redundant production/process equipment, pallets, packing materials, etc.

235. However, the generation of some wastes produced during recovery process is inevitable and cannot be recycled or reused and, therefore, they will need an environmentally sound destination for disposal. Tests should be carried out to determine if they can be disposed of as a non-hazardous waste or whether the lead content is sufficiently high for the waste to be treated as hazardous wastes that requires to be disposed of in specially engineered hazardous waste landfills (see BC Technical Guidance D5 Specially Engineered Landfill[15]) where the lead and other contaminants cannot leach into the groundwater/soil.

236. Some of the unrecoverable wastes, such as separators, pallets and packing materials may be put through the furnaces should it be appropriate and meets sound environmental management practices.

237. Other wastes that may be generated from the recycling process is redundant equipment. This is likely to be contaminated with lead and should be tested to assess lead levels and suitable environmentally sound disposal routes.

## H. Pollution controls

219.238. The control of emissions from a recycling plant is an essential operation to minimise the impact on the environmental and human health. The permit for a licensed WLAB recycling plant will specify the types of pollution controls to be employed and the amount of monitoring to be undertaken to demonstrate compliance. The cost of pollution control and the treatment of effluents and dusts, and the containment of sulphur dioxide emissions can be in excess of 30% of the investment costs and operating costs when occupational health provisions are included. Guidance on the pollution control technologies that can be employed are contained for example in the EU BAT Reference Notes (Best Available Technology)[50] which cover the lead industry. In addition the Commission for Environmental Cooperation has developed environmentally sound guidelines covering WLAB plants in North America.[51] Other countries have their own guidance on pollution control technology. The potential pollution sources that need to be controlled include the following:

(a) Acid electrolyte and process effluents;

(b) Dusts;

(c) Fugitive emissions;

(d) Sulphur dioxide;

(e) Slags;

(f) Unrecoverable wastes.

### 1. Acid and process effluents

220.239. There are several operations around a recycling plant than can generate effluents. The direct discharge of untreated acid, process effluents, pollution control effluents, and rainwater into the environment without treatment would result in an adverse environmental impact and potentially have significant harmful health implications for local communities and is to be avoided. The sources of process effluents are shown together with typical treatment options/uses in the table 1 below:

**Table 1: Potential effluent sources and treatment techniques**

| Process unit | Operation/source | Use/treatment options |
|---|---|---|

[49] http://synergies.pops.int/Portals/4/download.aspx?d=UNEP-CHW-WAST-GUID-SpeciallyEngineeredLandfill.English.pdf.

[50] https://eippcb.jrc.ec.europa.eu/reference/non-ferrous-metals-industries-0.

[51] http://www.cec.org/files/documents/publications/11665-environmentally-sound-management-spent-lead-acid-batteries-in-north-america-en.pdf

| | | |
|---|---|---|
| General | Rainwater from roads, yards, roofs, wet cleaning of roads, cleaning of lorries, etc. | Wastewater treatment plant then reuse or recirculation |
| Battery separation | Process liquor | Used in the desulphurisation process/wastewater treatment plant |
| Paste desulphurisation | Process liquor | Used in the desulphurisation process/wastewater treatment plant |
| Smelting and melting operation | Cooling water from furnace, machinery and equipment | Recirculation |
| Slag granulation | Wet ESP effluent. Granulation water | Recirculation, wastewater treatment plant. Recirculation |
| Gas-cleaning system | Condensate from gas cooling and wet ESP. Condensate from mercury removal | Removal of suspended dusts and reuse as raw material, wastewater treatment plant. After mercury removal, to wastewater treatment plant. Recirculation |
| Sulphuric acid | Battery breaking | Neutralisation and discharge via wastewater treatment plant Collection and reuse Gypsum production |
| Feed storage | Surface water (rain/wetting) | Wastewater treatment plant |
| Sinter plant | Scrubber (sinter fine cooling) | Wastewater treatment plant |
| All process units | Maintenance | Wastewater treatment plant |
| Wastewater treatment plant | Effluent treatment | Reuse for certain applications/discharge |

~~221.~~240. There are some technologies available to remove and recycle the electrolyte. These technologies provide a means to produce lead-free acid, which can be used as battery electrolyte again or sold as dilute sulfuric acid.

~~222.~~241. The electrolyte may be treated with sodium carbonate or calcium carbonate, to produce sodium sulphate or gypsum which can be further purified and sold to the cement industry as an additive, or the building trade for use in wall boarding.

~~223.~~242. The direct discharge of neutralized electrolyte into water sources, rivers, lakes and so on, should be avoided.

~~224.~~243. All lead recycling plants should be contained and have an effluent containment lagoon together with some form of treatment unit to either treat the effluent or evaporate it naturally in the case of hot climate. Any wastewater discharged from the recycling facility, including effluent neutralization, rainwater, spilled electrolyte, cleaning water, etc., should be captured, contained, tested, and treated prior to discharge to protect and maintain the quality of water resources. Modern operations should be designed or modified such that there is a closed loop for the containment of effluent. Treated effluent can be used as a coolant in the casting process or for damping down dusty areas to control fugitive emissions.

**2. Dust collection and air filtration**

~~225.~~244. At most the stages of operation the plant will release fume or dust which is hazardous to health. This should therefore be captured and collected and either returned to the plant or treated before the process gases are released to the environment. On average a recycling plant has to filter around seventy tonnes of air for each tonne of produced lead, it is evident that this is an important process to monitor and control.

226.245. The so-called “mechanical” dust, i.e., particulate material with large physical characteristics, is relatively easy to filter and remove from the process gases and the hygiene air. However, the finer the dust, formed as fume condenses, is more difficult to remove and special techniques should be employed to clean the gases and the hygiene air prior to release. There are a wide range of options available and the choice of the most suitable has to be judged as a function of meeting the legal requirements regarding air emissions and the expected contamination levels and the budget. There is a choice of fabric or bag filters, electrostatic precipitators, wet electrostatic precipitators, cyclones, ceramic filters, or a combination of two or three capture strategies, and whether a wet scrubber is needed as the final clean up and capture phase just prior to the release to atmosphere. Where possible all collected dusts should be redirected toward the smelting plant to recover lead. Collection of the baghouse or filter plant dusts should be into sealed bags or drums that can be charged directly to the furnace to minimise the risk of dust escaping into the operating areas.

### 3. Fugitive emissions

Commented [BRS38]: SIWG to consider more information on this section, see comments submitted.

227.246. Fugitive emissions represents one of the largest sources of lead contamination from a WLAB recycling facility. There are several ~~potential~~ sources of fugitive emissions resulting from material handling, vehicles, wind erosion from storage piles, and other uncontrolled sources but also from the "red" hot molten lead as it is drained from an unventilated smelting furnace caused by the high vapour pressure of lead and its compounds at about 1000ºC. Fugitive emissions can be generated if lead furnace bullion is transferred in an open ladle or “pot” at about 1,000ºC and poured into an unventilated refining kettle, and later during processing if the dusty drosses are skimmed manually without extraction or local ventilation.

228.247. There are several ways to control fugitive emissions and enclosing areas where fugitive emissions may originate is considered best practice. The minimum requirement for control of fugitive emissions involves; cleaning road pathways at least twice per day, ensuring that storage piles in the battery breaker are partially enclosed and wet, ensuring that the furnace, refinery, and casting areas are enclosed, and ensuring that any material storage and handling areas are enclosed and are wet for dust suppression, and there are vehicle wash stations at the exit.

229.248. There are two main ways of controlling fugitive emissions from molten lead source:

(a) Controlled extraction ventilated charging and tapping of the furnace feed and lead bullion. The lead bullion can be either cast into a 1,2 or 4 tonne mould and then allowed to solidify under a ventilation hood. Only when the lead block has solidified will it be moved to the refining kettle and then gently melted into a liquid bath of molten lead. Any dross produced should be removed in a procedure that ventilates the working area and extracts and contains any dust produced in a baghouse filter system;

(b) Tapping the red-hot molten lead from the furnace through a ventilated refractory launder into a bath of molten lead in a ventilated kettle, where the lead bath is about twenty degrees above the freezing point of lead and well below the temperature that can produce fugitive emissions. The bath of molten lead should be covered and ventilated so that any emissions would be removed to the baghouse. As the refining kettle containing the bath of molten lead fills, the lead may be pumped to another kettle to start the refining process.

### 4. Sulphur dioxide control

230.249. Many countries have very tight sulphur dioxide ($SO_2$) emissions which is an important pollutant to control due to its adverse environmental impacts. Its elimination by desulphurisation can be carried out before, during, or after smelting.

231.250. Desulfurization prior to smelting involves the removal of the sulphurous compounds via an aqueous reaction with either sodium carbonate or sodium hydroxide. The battery paste is mixed in a reactor with either compound, although carbonate is the common method due to costs. The lead carbonate product is sent to the smelter, but the sodium sulphate (a highly soluble product) requires a separate complex crystallizer or vaporizer plant, to recover a saleable product. The soluble sodium sulphate product should not be disposed from a smelter in the water courses.

232.251. During smelting desulphurisation can be carried out using iron and sulphur which have a great affinity for each other and will form FeS, (ferrous sulphide) in the furnace. Therefore, iron should be added to the furnace charge material along with a carbon in a metallurgical balance during smelting. The lead sulphate is reduced to lead sulphide and the iron combines with the sulphur, along with sodium, to form sodium lead sulphide called ‘Erdite’ and it reports to the slag. Iron/steel drums used for collecting baghouse dust can be sealed and charged to the rotary furnace. This has a dual advantage: the lead-containing baghouse dust re- mains enclosed throughout the handling processes and the iron of the steel drum acts as a sulphur binding/capturing agent during the smelting process. Feeding lead-containing residues such as baghouse dust back into the furnace is a crucial measure to recycle hazardous process by-product.

233.252. After smelting desulpurisation can be carried out by dry, semi-dry, semi-wet and wet processes, and a simple alternative is the use of wet scrubbers with calcium carbonate ($CaCO_3$) solution as reagent, which produces gypsum (Calcium Sulphate). Scrubbers are increasingly being employed to remove the final traces of sulphur dioxide after filtration.

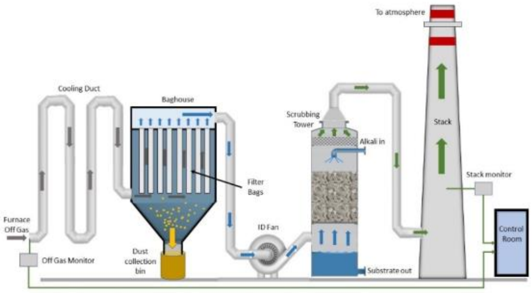



*Figure 9: Flue gas desulphurisation*

## 5. Use of oxygen

234.253. Oxygen ($O_2$) is used to enrich the combustion fuel used in the furnace processes with the following consequences:

(a) Since air has a big percentage of nitrogen [($N_2$, ~72% (v/v))] which does not participate in any chemical reaction at normal temperatures, the addition of pure oxygen ($O_2$) decreases dramatically the amount of combustion off-gas formation (by around five times);

(b) Decrease heat loss, since less cold gas is flowing through the furnace;

(c) DnIncrease furnace production because cycle times are reduced;

(d) Reduces the ventilation requirements to capture the off-gasses and so reduces the energy consumption required to power the baghouse.

235.254. Using pure oxygen to enrich the air supply to the furnace burners provides a much cleaner production process and is more energy efficient.

## ~~6.1. Slag wastes~~

~~236.1. Slags are the major hazardous waste formed during the whole process once the battery electrolyte has been removed, contained, and treated. Battery processing slags account for 13%-25% of the weight of lead produced. The method of dealing with slag wastes depends on the leachability of the metals they contain, and this is determined by the fluxes used and the operating conditions. Either calcium carbonate or sodium carbonate is added producing a calcium or soda slag.~~

~~237.1. Adding lime, calcium carbonate ($CaCO_3$), to the furnace produces a non-leachable slag, which is a more environmentally sound furnace residue waste. It increases the temperature of the furnace and produces more sulphur dioxide, resulting in higher energy costs and affecting the life of the refractories. Lime is much easier to deal with than sodium carbonate ($Na_2CO_3$) which produces a leachable slag.~~

~~238.1. Sodium slag tends not have any use due to its physical and chemical properties, and, therefore, it tends to be disposed of as a hazardous waste to a regulated hazardous waste landfill. In some cases, it is possible to reprocess it for cement addition to stabilise the slag for use in paving slabs or building bricks (subject to passing the appropriate building regulations and leachate tests) but this is not yet widespread.~~

~~239.1. Calcium slags can be used as a raw material in cement production in road building, bricks, etc. A calcium-based flux may be considered as a viable option since it provides a stable furnace slag.~~

240.1. The key to using slags rather than disposing of them to a specially engineered hazardous waste landfill depends on minimising its leachability and the lowering metal levels. Where this is not currently possible the slags should be disposed of at specially engineered hazardous waste landfills (see technical guidelines on specially engineered landfills that have been developed by UNEP Basel Convention[52]).

### 7.1. Unrecoverable wastes management

241.1. In theory it is possible to either recycle and recover or use all the WLAB components in the recycling process in such a manner that there are no waste materials to dispose of, apart from the separators and other materials associated with the production processes such brick furnace linings, redundant production/process equipment, pallets, packing materials, etc.

242.1. However, the generation of some wastes produced during recovery process is inevitable and cannot be recycled or reused and, therefore, they will need an environmentally sound destination for disposal. Tests should be carried out to determine if they can be disposed of as a non-hazardous waste or whether the lead content is sufficiently high for the waste to be treated as hazardous wastes that requires to be disposed of in specially engineered hazardous waste landfills (see BC Technical Guidance D5 Specially Engineered Landfill[15]) where the lead and other contaminants cannot leach into the groundwater/soil.

243.1. Some of the unrecoverable wastes, such as separators, pallets and packing materials may be put through the furnaces should it be appropriate and meets sound environmental management practices.

244.1. Other wastes that may be generated from the recycling process is redundant equipment. This is likely to be contaminated with lead and should be tested to assess lead levels and suitable environmentally sound disposal routes.

### 8.6. Environmental monitoring

245.255. Environmental monitoring of the operations is essential to be confirm compliance with the permit. It can be regarded as an environmental contamination thermometer. The data collected can be used to measure performance and detect equipment failures when connected to an alarm system. It can also be used as a source of credibility and trust in the relationship with the regulatory authorities and local community since lead recycling plants are usually regarded as a potential source of environmental contamination and population lead exposure.

246.256. Wastewater from scrubbers, electrostatic precipitators, plant cleaning wastewater, battery breaking, slag granulation and rainwater runoff should all be directed to the effluent treatment plant for discharge and monitoring.

247.257. Air emissions from the plant processes and hygiene air should be directed to pollution abatement plant and monitored via the stack. Diffuse emissions from around the plant will require monitoring and a number of measures and techniques are available.

248.258. Each plant should use recognised monitoring equipment and techniques for checking effluents and wastewater discharges, air emissions, air quality and soil, vegetation, and groundwater.

249.259. Wastewater/effluents: following treatment at an effluent treatment plant, any effluent, including surface water, leaving the plant should be monitored at a minimum for pH, lead content (dissolved and suspended), other representative heavy metals (As, Hg, and Cd) and sulphates, BOD, COD. Where possible automatic sampling and monitoring should be undertaken and where appropriate connected to an alarm system to alert personnel in the event of plant failure.

250.260. Air emissions: continuous or regular monitoring of the furnace off-gases for sulphur dioxide ($SO_2$), NOx, metals (lead), dust and VOCs and PCDD/F. Stack emissions are normally monitored on a continuous basis and there should be an alarm to alert personnel in the event of plant failure (e.g. split bags in the baghouse). In addition, boundary lead in air monitoring should be performed at several locations around the plant to measure airborne particulates (lead).

251.261. Dioxins and furans are aromatic organic compounds formed by relatively low temperature thermal reactions together with the presence of chlorine and is a carcinogen. Secondary raw materials containing chlorine together with the furnace environment may provide good dioxin formation conditions, particularly when the furnace is being charged. Also, the use of carbon reducing agents and fuels may produce a fine carbon powder that, under specific conditions, may react with chlorine

[52] http://synergies.pops.int/Portals/4/download.aspx?d=UNEP-CHW-WAST-GUID-SpeciallyEngineeredLandfill.English.pdf.

derivatives and produce toxic compounds. Also, the presence of copper and iron, both commonly found in lead recycling processes, seems to catalyse dioxin and furan formation.

252.262. PVC separators are no longer used in battery manufacturing so that risk of dioxin formation is greatly reduced. But with iron and copper being in the feedstock it is not totally eliminated. Oxygen enriched air or pure oxygen can be used to ensure complete combustion of organic compounds to reduce the risk of dioxin formation. Activated carbon can also be injected into the gas stream to absorb the organic molecules and, afterwards, be filtered. The filtered dust is a hazardous waste and should not be put in the furnace but disposed of by high temperature incineration.

253.263. Maintaining complete high temperature combustion of all furnaces is an effective means of control. Monitoring stack emissions is important for checking and ensuring emission levels are below 0.5 ng per cubic meter can be achieved and it should not be difficult to achieve levels below 0.1 ng per cubic meter.

254.264. Air quality: regular monitoring of the air quality inside the enclosed buildings and control cabins/offices, battery breaker, furnace, and refinery to monitor compliance with lead in air limits within the work areas for occupational exposure.

255.265. Soil, vegetation, and groundwater: periodic monitoring of soils, vegetation and groundwater should be performed to establish whether the operations are impacting the environment and whether any action needs to be taken.

## I. Management of contaminated sites

Commented [BRS39]: SIWG to consider reviewing this section to make it complete and accurate.

### 1. Identification, investigation and assessment

256.266. Land is classed as contaminated where substances are causing or could cause significant harm to people, property or protected species or significant pollution of surface waters (for example lakes and rivers) or groundwater.

257.267. Sites where lead-acid batteries have been manufactured, collected, broken and/or recycled would fall into this category especially if the ground was unprotected. A site assessment and site investigation would need to be carried out to determine whether the ground and groundwater is contaminated, what contaminants are present and there levels to assess what further action, if any, needs to be undertaken.

258.268. The site assessment should establish what operations occurred on the site, a location plan of the operations and possible areas of concern (e.g.,WLAB storage area, slag storage, waste disposal area, etc.). This would form the basis of determining where to carry out any intrusive soil and groundwater investigations.

259.269. Following the site assessment, a soil and groundwater investigation may need to be carried out based on the information from the site assessment. The results from the site investigation would then determine whether more detailed investigations would be needed and where they are required. The results from this would establish the nature and extent of any soil and groundwater contamination. In the event of groundwater contamination there would be a need to evaluate hydrogeological impact of this on aquifers and surface water, especially if there is evidence of contaminants migrating off site.

260.270. A risk assessment should then be prepared setting out the nature and extent of contamination, the risks it may pose and to whom/what (the ‘receptors’). The risks identified can be assessed to establish whether they can be satisfactorily reduced to an acceptable level. Land use screening levels can be used in providing a simple test for deciding when land is suitable for use and help to decide what the land can be used for, for example, industrial, commercial, housing, or agriculture based on the level of contamination and the risks it presents. Soil reference values have been developed (e.g. California[53], UK, Netherland[54] Netherlands [references to be inserted]) to assess contamination levels and acceptable use values.

261.271. Following these stages an environmental impact assessment report should be produced setting out the former use of the site, what activities took place, areas of concern, a description of the contamination, a description of the likely effects and impacts both on and off-site, description of what the land can be used for, description of the works, if any, needed to rectify the impact. This

[53] California EPA, https://oehha.ca.gov/risk-assessment/sites
[54] Dutch Intervention values; https://www.pbl.nl/sites/default/files/downloads/711701023.pdf

information can then be used to set the basis for the use of the site and providing the authorities and community with the relevant information.

### 2. WLAB site decommissioning

~~262.~~272. The process for closure and decommissioning of a WLAB site broadly falls into five distinct phases:

(a) Phase 1 is initial information gathering, due diligence, identification of the key stakeholders and understanding the legal and contractual obligations that may be in place;

(b) Phase 2 involves agreeing the necessary studies that need to be carried out to categorise the environmental status of the site in liaison with the authorities and (if applicable) the landlord and gaining an understanding of the level of clean-up that is required and obtaining approval from the authorities regarding soil/groundwater clean up levels;

(c) Phase 3 involves carrying out any further investigations, characterising the site and finalising any requirements for remediation with the authorities. Also included in this phase are the negotiation and finalisation of the contracts;

(d) Phase 4 is the actual carrying out of the works and the supervision of them;

(e) Phase 5 is the verification that those works have been carried out to the satisfaction of all stakeholders and finalising surrender and exit.

~~263.~~273. During the decommissioning works it is important that they are carried out in a way that minimises the environmental, health and safety impacts on the workers, local community and the environment. Part of this phase should involve site clean-up to remove as much of the lead contamination and lead contaminated equipment/plant as possible under controlled conditions.

## J. Health & Safety

### 1. General considerations

~~264.~~274. Lead is a naturally occurring and abundant element in the environment. Natural mobilization of lead occurs by weathering of mineral deposits and gaseous emissions, such as volcanic eruptions. It has been estimated that, together, these two mechanisms release as much as 210,000 tonnes of lead into the environment each year and were, until the appearance of human activities, the only source of environmental lead.

~~265.~~275. In comparison human activities release lead from its natural sources much more intensely, amounting more than 6 million tonnes/year, yet just a small fraction of this returns to the environment as a contamination source whereas the major part is directed to industrial processes.

~~266.~~276. The major sources of lead are shown in the following diagram (Fig 10).

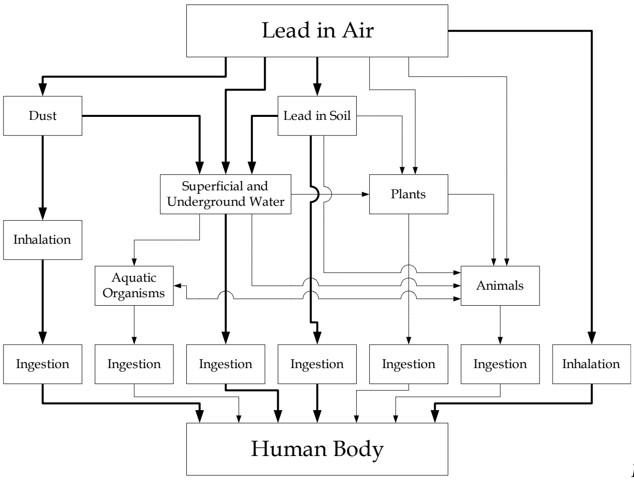



*Figure 10: sources of lead into body*

**Commented [BRS40]:** SIWG to consider reviewing and improving this section.

SIWG to add references/sources of information on the values mentioned in this section.

SIWG to add other relevant references for example from WHO, among others, and to simplify this section to make use of terms that could be easily understood.

SIWG to include information on other impacts on human health.

**Commented [BRS41]:** SIWG to look into paragraphs 275 and 276 and the remarks regarding antropogenic emissions of lead.

~~267.~~277. The lead industry is a significant source ~~potential~~ and magnifier of the natural lead sources if the appropriate occupational and environmental controls are not implemented. It is important that both workplace controls and emissions controls are implemented to reduce the risks to human health from waste lead-acid battery recycling.

~~268.~~278. Human exposure to lead is universal and everyone carries a body burden of lead with background levels typically less than 4ug/dl for non-occupationally exposed adults. The primary routes of exposure are by inhalation and ingestion. Dermal absorption of inorganic lead through unabraded human skin is considered minimal. Lead from both natural and industrial sources is present in the air, food, water and soil.

~~269.~~279. Lead is absorbed in the body via ingestion and inhalation. The route of uptake depends on the size of the particle and the type of lead compound (organic or inorganic), together with the concentration and possible diffusion of the metal throughout the body. Lead absorption also depends on physiological state and tissue integrity, age and nutritional, metabolic and anatomic conditions. A general scheme of the lead distribution may be seen in figure 11.

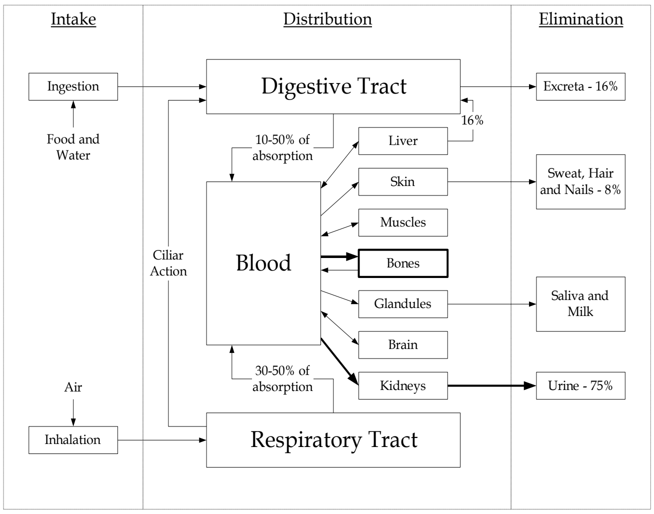



*Figure 11: Lead in the human body*

~~270.~~280. Inhalation and ingestion are the main route of lead absorption in the industrial environment if the hygiene control protocols are not followed such as not wearing respiratory protection equipment and gloves and poor personal hygiene and hand to mouth exposure. Around 20-40% of lead that enters the respiratory tract remains in the body, and a major part of it is directed from the respiratory tract to the stomach by ciliary means. The amount that remains inside the lungs is rapidly absorbed by a process that is independent of the chemical species of lead involved. It is estimated that a concentration of 1 µg.m$^{-3}$ of lead in the air produces a concentration of 1-2 µg/dl in the blood stream.

~~271.~~281. Absorption of lead through the skin is considered negligible. However, lead on the skin can easily be transferred from hand to mouth, for example.

~~272.~~282. Gastrointestinal absorption, which is the main non-industrial intake route, can also play a significant role in occupational settings through hand to mouth transfer, e.g smoking and eating with dirty hands. Approximately 10% of the total lead ingested may be absorbed.

~~273.~~283. Children are thought to absorb more lead than adults and some data shows that the absorption following ingestion may be as high as 50%, i.e. five times greater than that seen in adults. It is for this reason there is a need to ensure that child contact with lead is prevented.

~~274.~~284. The absorbed lead is transported to the blood stream where a rapid equilibrium is established between plasma and red cells in a proportion of 1:16. From the blood stream, the lead is delivered to all organs, especially bones which may retain around 90% of the body's lead content. Therefore, while the blood lead concentration reflects recent exposure, bone lead concentration better reflects longer- term exposure.

~~275.~~285. Urine is the primary route of excretion. Ingested lead is mainly passes through the faeces, reflecting the poor gastrointestinal absorption rate. Lead absorbed by the body and incorporated into the blood stream is eliminated by urine (75% - 80%), gastrointestinal secretions through the liver (16%) and hairs, nails and sweat (8%).

~~276.~~286. Breast feeding women may also eliminate lead through their milk in a concentration similarly to the plasma. This may be a significant source of lead in infants of women with high lead exposure and is a significant reason to ensure that women of childbearing age are protected from lead exposure. Lead may also cross the placenta and thus pose a significant risk to the unborn child and should therefore be a reason to exclude women of childbearing age working in a lead plant.

~~277.~~287. The half-life of lead in the body varies according to the tissue. It is almost impossible to determine its elimination rate, since the bones may have a large quantity ready to mobilize into the blood stream. Nevertheless, some half-lives are known for blood and soft tissues (30-40 days) and bones (in excess of 20 years). This means that individuals with little or no current lead exposure may still have relatively high blood lead levels for many months or even years after exposure has ceased.

**(a) Toxicity & health effects**

~~278.~~288. There is a vast database on the effects of lead on human health. Lead has been shown to have diverse biological impacts in humans involving cardiovascular, nervous, gastrointestinal, renal, haemopoietic, reproductive, genotoxic and carcinogenic effects.

~~279.~~289. The toxicity of lead is thought to be due to the lead cation and most studies relate to the amount of absorbed lead and its effects. The toxic mechanism of lead poisoning may be by:

(a) Competing with other essential metabolic metals such calcium and zinc;

(b) Its strong affinity by sulphidril (-SH) groups in proteins, which means that several proteins may be chemically changed and become dysfunctional and reflecting badly in several metabolic paths;

(c) Altering the transport of essential ions throughout the body.

~~280.~~290. A wide range of heterogeneous effects and general and unspecific symptoms have been described and associated with lead contamination and they can be found in Annex 2. The most affected human body systems by lead exposure are:

(a) Haematopoietic system: one of the earliest and most important effects of lead contamination in the human body is the alteration in the synthesis of the haem group, leading to anaemia as a result of red cell modifications;

(b) Central nervous system (CNS): the effects of lead in the CNS are important in young children and neuropsychological effects may occur even for exposures considered as sub-toxic in adults, at blood lead levels as low as 5µg/dl. However, prolonged lead exposure in adults may also produce significant adverse effects on the CNS, causing what is known as saturnine encephalopathy, which symptoms range from subtle psychological and behavioural changes to severe neurological alterations. Besides, there is a difference of effects as the lead source changes from inorganic lead to organic lead;

(c) Peripheral Nervous System (PNS): the inorganic lead produces adverse effects in the PNS, not only in the structure but also in the biochemical behaviour of the nerves. The most characteristic effect is the saturnine palsy which the major expression is the lack of strength in the wrists.

~~281.~~291. Lead exposure affects the kidney's, gastrointestinal system, cardiovascular system (including impacts on blood pressure), male reproductive system (adversely impacting fertility), endocrine system and joints.

~~282.~~292. Of particular concern is lead exposure to women of childbearing age and they should be considered as a sensitive sub-population due to the ~~potential~~ impacts on the health and wellbeing of their unborn child. Lead induced toxicity to the foetus via maternal exposures can take the form of adverse effects on neurological development. Breastfeeding women can also pass on lead to the child which can also result in adverse outcomes.

~~283.~~293. The European Chemicals Agency (ECHA) Scientific Committee has reported on the health effects of lead and its compounds (ECHA 2019). These are covered in the following items:

(a) Neurobehavioral effects – the effects which are considered to appear adverse appear in a number of studies for PbB greater than 40ug/dl;

**Commented [BRS42]:** SIWG to review this paragraph and its sub-items and to check accuracy if it remains in the document.

(b) Renal effects – exposure to high levels of lead (>60ug/dl) may cause renal disfunction. There appears to be no evidence of nephrotoxic effects at levels of PbB below 40ug/dl;

(c) Blood pressure – studies report that a small increase in blood pressure can be observed for a PbB >30ug/dl. However, a small effect on blood pressure is not considered a health outcome per se but a risk factor for cardiovascular and cerebrovascular disease;

(d) Haematological effects – lead inhibits enzymes of haem synthesis and may occur below 40ug/dl but are not considered adverse;

(e) Carcinogenicity – lead salts in experimental animal carcinogenicity is directed to the kidneys, while epidemiological data concerning carcinogenicity are inconsistent. It is not considered mutagenic in most test systems, chromosomal aberrations and sister-chromatid exchanges have been observed in cell cultures, experimental animals and in exposed workers. It is thought that carcinogenicity is probably due to indirect mechanisms such as inhibition of DNA repair. There is ongoing discussion on human carcinogenicity of lead as there is limited evidence of cancer;

(f) Reproductive effects – exposure of male workers to lead may affect semen quality and sperm DNA integrity that could lead to reduced fertility and miscarriages in the partner. Adverse effects on male fertility could appear at PbB >40ug/dl.

## 2. Exposure limits Occupational exposure - air

284.294. Establishing the appropriate control measures should be based on an assessment of risks and the controls needed to minimise them. Comparing occupational/biological exposure levels and limits will help identify the risk and the control measures needed to protect human health.

285.295. Setting lead in air limits for the workplace does not ensure that at lower concentrations there will be no adverse effects for anyone exposed. Furthermore, it should be understood that:

(a) Threshold values were determined in developed countries where the labour conditions, as well as the health and physical conditions of the workers, are often very different from those in developing countries or those in transition;

(b) Workers are exposed to various substances that may have synergic or addictive effects with each other (e.g., smoking);

(c) They were based on an eight-hour adult workday, five days a week, whereas it is not uncommon to find much longer working hours, a longer working week, and also the employment of children in developing countries (particularly in small family businesses).

286.296. It is important to understand that lead exposure limits and others, become lower and more restrictive, as more information and identification of issues at lower concentrations becomes available.

297. The threshold limits shown here should be used as a guide to protect those directly exposed. It is important to understand that information from systematic biologic surveillance (i.e., blood lead measurements) are a better indication of lead exposure and risk in a particular population. Table 12 provides an overview of occupational lead exposure limits.

Table 2: Occupational Lead Exposure Limits[55,56,57]

| Jurisdiction/standard setting body | Occupational Exposure Limit |
|---|---|
| US ACGIH TLV (2001), Safework Australia (2014), China-National Health Commission (2019) | 50µg/m3 (8hr TWA) |

~~Table 1: Occupational Lead Exposure Limits[58,59,60]~~

287.298. The principle of most of the methods to monitor lead in air concentrations is by using a particle sampler (for inhalable fraction) to trap a sample. Lead compounds are then extracted into

55 https://www.osha.gov/lead
56 https://echa.europa.eu/oel
57 https://www.safeworkaustralia.gov.au/safety-topic/managing-health-and-safety/exposure-standards-airborne-contaminants
58 ~~https://www.osha.gov/lead.~~
59 ~~https://echa.europa.eu/oel.~~
60 ~~https://www.safeworkaustralia.gov.au/safety-topic/managing-health-and-safety/exposure-standards-airborne-contaminants.~~

solution and further analysed using a suitable technique (e.g., atomic absorption). See table 23 for further information.

*Table 23: Methods for lead and lead compounds in air*

| Method | Analytical Technique | LOQ and sample volume/time | Reference |
|---|---|---|---|
| BGI 505-73-01 (inhalable) | GF-AAS Graphite furnace atomic absorption spectroscopy | 0.13 µg/m3 for a 1200l sample (2 hours)<br>Flow rate: 10 l/min | DFG, 2012 |
| ISO 15202 | ICP-AES (Inductively coupled plasma atomic emission spectroscopy) | 17 µg/m3 for a 480l sample (less than 1 hour) | ISO, 2012 |
| MDHS 91-2 (inhalable) | XRFS (X-ray fluorescence spectrometry) | 2 µg/m3 for a 480l sample (4 hours)<br>Flow rate: 2 l/min | UK HSE |

*Table 2: Methods for lead and lead compounds in air*

**(a) Biological exposure limits (blood lead)**

288.299. There is not strong relationship between the amount of lead the body absorbs and the concentration of lead-in-air. For that reason, use of biological exposure limits are advised.

289.300. Lead in blood (PbB) is the most prominent and best validated biomarker for establishing a biological value for assessing lead exposure. The parameter provides a high sensitivity for current lead exposure and depicts an intermediate observation time featured by an elimination half-time of about one month.

301. Biological limit values vary amongst regulators, but recent scientific experts have indicated that BLV's should be below 30µg/dl to protect employee health. Table 34 provides further information on health basedhealth-based blood lead limits.

*Table 34: Health based blood lead limits established by independent scientific bodies*

| Institution | Biological Limit Value | Comment |
|---|---|---|
| EU SCOEL (2002) | 30µg/dl | subtle effects in neurobehavioral tests at 40µg/dl |
| US ACGIH (2017) | 20µg/dl | various neurological and neurobehavioral effects and effects of reproduction can be seen down to 20µg/dl |
| Japan - Society for Occupational Health (2018) | 15µg/dl | |

*Table 3: Health based blood lead limits established by independent scientific bodies*

302. Current scientific margins of risk have been established for blood lead levels (see Table 45).

*Table 5 Workplace Exposure Risk Levels based on Blood Lead Concentration*

| | Risk Level (male employees) | | | |
|---|---|---|---|---|
| | Minimal | Acceptable | Excessive | Dangerous |
| Pb concentration in blood (µg/dl) | < 20 | 20-30 | 30-50 | > 50 |

*Table 4: Workplace Exposure Risk Levels based on Blood Lead Concentration*

290.303. Women of childbearing potential are a sensitive sub-population to the adverse effects of lead exposure and blood lead concentrations and should be as close to background concentrations as possible as seen in non-occupationally exposed populations typically less than 4ug/dl.

291.304. Suspension or removal from further exposure should be considered for those with blood lead concentrations above certain values. In many jurisdictions, suspension from the workplace is mandated when an employees' blood lead level exceeds 30µg/dl and it should certainly be considered for anybody with a blood lead exceeding 50µg/dl.

**(b) Environmental limits**

292.305. The establishment of environmental limits is recommended to protect human health in the general population but also flora and fauna. As is the case with occupational exposure limits, these limits help define the risk management measures that should be adopted at a WLAB recycling plant.

293.306. People can become exposed to lead from environmental sources as a result of: inhalation of lead particles generated by burning materials containing lead, for example, during smelting, recycling, stripping leaded paint, and using leaded gasoline or leaded aviation fuel; and ingestion of lead-contaminated dust, water, and food grown nearby.

294.307. Determination of blood lead levels may be required as part of a health risk assessment for a population at risk of being exposed to lead, such as villagers living in the vicinity of a WLAB recycling or lead processing factory. A portable ASV device (such as "LeadCare"), that does not require skilled laboratory personnel for its operation, can be used.

295.308. There is no known 'safe' blood lead concentration for the general population; even blood lead concentrations as low as 5 µg/dl, may impact children's intelligence and cause behavioural difficulties and learning problems.

296.309. Typical background blood leads for an average adult is usually less than 4ug/dl depending on a range of factors such as age, diet, whether you smoke, where you live and environmental background levels. Blood lead levels for those living in areas where lead has been mined for example may be higher due to the presence of lead in the soils and vegetation. There is also a risk from cookware and earthen ware pottery in some areas of the world that can give rise to elevated levels.

297.310. Examples of non-occupational lead exposure limits are:

| Source | Limit |
|---|---|
| General population blood levels of concern in children | USA, 5µg/dl (based upon 97.5% of population) (US CDC, 2012) |
| Potable Water | 10µg/l (provisional) (WHO, 2011) |
| Food | Not possible to establish a PTWI (JECFA (2010) |
| Ambient Air | 0.5 µg/m3- average annual concentration (EU, 2008) |

*Table 65: Environmental lead exposure limits*

**3. Prevention & control**

298.311. The key to controlling employee/contractor to lead exposure in the workplace is to ensure the following:

(a) There are engineering controls in place to minimise and control the presence of lead contamination in the work area. Such controls include dust and fume extraction and abatement systems (e.g., mist sprays), and containment systems (e.g., hoods);

(b) That there are established workplace practices and standard operating procedures (e.g., as an example those developed for use in Ghana with a view for a wider use and uptake[61]) in place to minimise the risk of exposure these include housekeeping and hygiene controls, sweeping and cleaning measures and equipment and that all employees/contractors have been properly trained in what to do in the workplace and the procedures to follow;

(c) Providing all employees with personal protection equipment (PPE e.g., overalls, socks, jackets, shirts, boots, gloves, helmets, safety glasses) and respiratory protection equipment (RPE e.g., face masks) to minimise exposure to lead and reduce the risk of elevated blood leads;

[61] https://www.sustainable-recycling.org/wp-content/uploads/2022/04/ULAB_recycling_SOPs.pdf

(d) Daily changes of work clothing/uniform or more frequently if dirty;

(e) Undertaking employee/contractor training/retraining on blood lead management measures. Specific education and awareness materials should be made available to employees/contractors and also their families;

(f) Undertaking counselling and retraining for anyone with an elevated blood lead;

(g) Removing contaminated clothing/PPE before entering a clean area (e.g. ,canteen, office's, etc.);

(h) Requiring anyone exposed to lead to shower, scrub their nails and wash their hair at the end of the working day before putting on their own clean clothing at the end of the day;

(i) No contaminated work clothing to be taken home by employees to wash (all workplace clothing to remain on site);

(j) To minimise the risk of elevated lead levels employees should ensure they do not bite their nails, rub their face with contaminated hands or gloves, do not eat or smoke in the workplace and do not have facial hair that adversely affects the use of RPE;

(k) Women of childbearing age should not be allowed to work in a WLAB recycling plant, except in areas where there is no risk such as an office or canteen;

(l) Children should not be allowed to work in a WLAB recycling plant or handle lead acid batteries.

### 4. Engineering controls

~~299.~~312. Effective engineering controls should be regarded as the first line of control in minimising the risk of workers and others of being exposed to lead. They are the type of controls that protect everyone by removing hazardous conditions or by placing a barrier between the worker and the hazard. These controls should focus on the source of the hazard, unlike other types of controls that generally focus on employees being exposed to the hazard.

~~300.~~313. Engineering control are a piece of equipment, a machine, or mechanical device designed to minimise the harm associated with a hazard. Engineering controls can reduce harm by:

(a) Isolating workers from the hazard (e.g., enclosed furnace/refinery control cabin);

(b) Enclosing high risk operations (e.g., an area that is only opened during maintenance and cleaning);

(c) Extracting lead fume and dust in the work area (e.g., installing Local Exhaust Ventilation (LEV) systems);

(d) Automating tasks so workers no longer need to perform them (e.g., using robots to skim drosses in refining kettle, loading the furnace, skimming molten lead ingots, stacking ingots);

(e) Automatic dust suppression spray systems to prevent lead dust becoming airborne;

(f) Automatic doors that open and close in lead storage areas.

~~301.~~314. The use of engineering controls in the recycling plant is an essential to reduce and control the levels of lead present in the work area and minimise the risk to employees.

~~302.~~315. Where feasible design the facility, equipment, or process to remove the hazard and/or substitute something that is not hazardous or is less hazardous.

(a) Redesigning, changing, or substituting equipment to reduce the generation of excessive dust and fume;

(b) Designing the ventilation with sufficient suction and flow to improve indoor air quality and generally to lead in air levels.

~~303.~~316. If removal is not feasible, enclosing the hazard to prevent exposure in normal operations should be considered, e.g,:

(a) Complete enclosure of moving parts of machinery;

(b) Complete containment of refinery kettles to reduce fugitive emissions;

(c) Complete containment of noise and heat.

~~304.~~317. Where complete enclosure is not feasible, establishing barriers or local ventilation to reduce exposure to the hazard should be considered, e.g.,:

(a) Ventilation hoods;

(b) Machine guarding, including electronic barriers;

(c) Isolation of a process in an area away from workers, except for maintenance work;

(d) Installing positive pressure control cabins and HEPA air filters to ensure the air in the work area is lead free.

~~305.~~318. For existing WLAB recycling plants consideration should be given to carrying out an assessment to identify engineering controls that could be undertaken to reduce the levels of dust and fume in the plant, this could include, but not limited to the following:

(a) Reviewing battery breaking operations;

(b) Reviewing paste storage and handling and ways of reducing lead becoming airborne;

(c) Establishing measures to reduce sulphur levels in emissions;

(d) Looking at furnace operations and furnace loading and tapping for controlling lead fume entering the work area;

(e) Assessing refining and the dedrossing of the kettles to reduce lead dust/fume being released into the work area;

(f) Reviewing dust handling of air emissions controls, e.g., bag houses.

## 5. Housekeeping

~~306.~~319. A clean plant is essential for minimising lead exposure and is as important as emission controls and hygiene measures.

~~307.~~320. Dust deposits should be removed on a regular basis to reduce the risk of contaminant dispersion. The methods of cleaning involved should take into account the need to minimise the spread of contamination. Either wet cleaning or the use of mobile equipment with high efficiency filters should be used. Dry brushing and sweeping should not be used because of ~~potential for~~ dust generation and spread of contamination.

~~308.~~321. Contaminated plant, equipment, containers, and tools, used for example by contractors, should be decontaminated, by water washing or other approved methods, prior to off-site removal. Any equipment to be maintained in a workshop should be cleaned prior to works being carried out to minimise risk of contamination.

~~309.~~322. High standards of cleanliness should be adopted to minimize the spread of contaminant and regular workplace checks should be carried out to monitor the effectiveness of housekeeping measures.

~~310.~~323. Within a plant there are a number of locations other than production areas which also present a risk of exposure, these include weighbridge office, canteen, break rooms, control rooms, offices, laboratory, toilets, showers, locker rooms, drivers cabs and other areas. A site-specific list of areas should be identified together with a cleaning frequency (e.g., number of times per day). For each specific area a monitoring frequency (e.g., weekly, monthly, quarterly) should be established to check lead in air for exposure and also swab testing to check the effectiveness of housekeeping. The swab testing of surfaces for lead should include tables, chairs, window ledges, cabinets, etc.

## 6. Personal protection equipment

~~311.~~324. It is important in the lead industry that employees/contractors work use personal protection equipment (PPE) to minimise their risk to lead exposure. However, employers should not rely on PPE alone to control exposure to lead where other effective control options are also available. PPE can be effective, but only when workers/contractors use it correctly and consistently. PPE might seem to be less expensive than other controls but can be costly over time, especially when used for multiple workers on a daily basis.

~~312.~~325. When other control methods are unable to reduce lead exposure to the established safe levels, PPE should be provided to reduce the exposure and PPE is the only control option available.

~~313.~~326. PPE in the WLAB recycling industry is indispensable to protect employees and contractors from exposure to lead. Each company should have site-specific procedures and PPE for employees, visitors and contractors. The procedures should include the type of equipment approved and available for use and the circumstances under which particular PPE is to be worn, type of equipment to be worn, issuance of PPE and maintenance and cleaning of PPE.

~~314.~~327. Each company should identify a person with overall responsibility for identifying, specifying and approving the type of PPE to be used and worn on site.

~~315.~~328. PPE requirements should be established for specific workplace activities (e.g. hot metal work, etc.) due to the variable operations and include the following categories:

(a) Works clothing/uniform;

(b) Head protection;

(c) Respiratory protection;

(d) Hand protection;

(e) Foot protection;

(f) Other protective gear.

~~316.~~329. PPE for use by employees, should, for example, include, where appropriate, the following:

(a) Work shirts;

(b) Under trousers;

(c) Overalls (boiler suit);

(d) Socks;

(e) Workplace footwear (e.g., leather metatarsal boots, wellington boots with steel toe-caps);

(f) Canteen clothing & footwear (e.g., plimsolls);

(g) Gloves, gauntlets etc. (nitrile gloves, foundry gloves, heat resistant gloves);

(h) Hard-hat (often this is part of a battery powered respirator);

(i) Safety glasses, face shields, goggles, etc.;

(j) Respiratory protection equipment (e.g., 3M battery powered helmet & respirator (3M Versaflow), or other powered helmet respirators, neoprene respirator, face masks with at least P2 or N95/FF2 protection, half masks with cartridges, etc.);

(k) Gaiters;

(l) Hearing protection;

(m) Hot metal work protection equipment (e.g., neck capes, kevlar gloves, leather aprons, etc.);

(n) Jackets and body warmers;

(o) Waterproofs.

~~317.~~330. PPE should also be available for use by visitors and include, where appropriate, but not be limited to hard hat, safety glasses, protective over garment e.g., disposable/washable boiler suit, lab coat etc., hearing protection e.g. ear plugs to be worn in designated hearing protection area,; respirator - to be worn in designated respiratory protection areas, and protective footwear (e.g., boots with steel toe caps).

~~318.~~331. PPE requirements for contractors should be established prior to commencement of site works. No contractor should carry out work on-site with their own PPE unless this has been authorised by the site person responsible for PPE to prevent contaminated clothing being removed from site.

~~319.~~332. Each employee should be provided with training regarding the use and wearing of PPE (e.g., respiratory protection equipment such as battery powered helmet respirators). No PPE, which requires specific specialist training prior to use, should be issued unless that training has been provided (e.g., breathing apparatus for furnace relining works).

~~320.~~333. PPE and RPE should be checked and cleaned on a regular basis and where it is identified as being unsafe, or not working properly should be withdrawn from use to ensure that those using the equipment are not at risk from exposure to lead.

### 7. Medical surveillance

~~321.~~334. All employees should have a medical examination when they commence employment. This will establish a health baseline that will allow a medical professional to identify any occupational related health issues, e.g., blood leads, loss of hearing and also any issues which may be present prior to their employment. The levels and frequency for blood leads are discussed in section 9 – blood lead monitoring together with the frequency of monitoring.

~~322.~~335. Regular follow-up health monitoring for example every 12 months should be undertaken to identify any occupational health issues that may arise from their employment.

~~323.~~336. Employees with any occupational health issues should be receive the appropriate medical support and treatment to address the issue of concern so that it can be resolved.

### 8. Blood lead monitoring

~~324.~~337. Occupational health monitoring and in particular blood lead monitoring is the main way an employees/contractors exposure to lead can be monitored and to that the risk management measures and procedures that are in place are effective.

~~325.~~338. Blood lead levels are the most reliable indicator of occupational exposure. Regular monitoring of employees and contractors should be carried out to identify any exposure issues and establish what mitigating measures should be undertaken if an issue arises. Elevated blood leads are a key indicator of any problems in the workplace with engineering emission controls, workplace procedures, hygiene practices or use of PPE/RPE.

~~326.~~339. All employees/contractors should have their blood leads tested on a regular basis by a medical professional (e.g., works doctor/nurse). The frequency of the sampling should depend on the level of lead in the blood. The higher the level the greater the frequency of testing. The relationship between high blood lead and high risk positions is not that clear given that many employees in high risk areas can have low blood leads. Consequently, the plant should establish the frequency of blood lead testing for anyone exposed to lead based on set blood lead levels, for example <15ug/dl every 3 months, 15ug/dl-20ug/dl every 2 months and >20ug/dl monthly.

~~327.~~340. The plant should also set an alert level and limit value. An alert level (e.g., 20ug/dl) would require an evaluation of work practices and ~~potential~~ routes of exposure to be evaluated to see what measure can be adopted to bring about a lowering of blood lead. A limit value (e.g., 30ug/dl) could be used to assess whether an employee needs to be reassigned to another work area or job to lower their risk of exposure.

~~328.~~341. The doctor/nurse will take a small sample of blood from a vein and send it to an approved/certified laboratory. The laboratory will return the result to the medical professional who will discuss the result with the employee/contractor. Preferably the medical professional will share the result with plant management so that they can see whether any action needs to be taken such as making changes to engineering controls, workplace procedures or changes to employee practices.

~~329.~~342. Lead exposure levels and contamination data are sometimes misleading because they do not always show the complete situation or reflect a person's attitude towards personal protection and procedures to minimise exposure. Employee behaviour in the workplace can play a key role in causing elevated blood leads and it is for this reason that assessing the way they work and undertake their tasks can shed light on potential causes and an opportunity to modify the way they work or follow hygiene procedures through counselling, guidance, or additional training/retraining.

## K. Emergency response

### 1. Emergency planning

~~330.~~343. The operation of a WLAB recycling plant involves various risks, such as fires (e.g. battery storage areas, bag houses, furnace explosions/fires, lead eruptions from refining kettles), stormwater and effluent overflows, etc. These ~~risks~~ all present risks ~~have the potential for~~ the release of lead and other substances and this should be considered/included as part of the planning. Given the ~~potential~~ risks of operation it is important that its operations and activities are reviewed and all areas where there are risks ~~is~~ ~~potential~~ for fires/explosions, spills or releases of hazardous/polluting materials may occur, and off-site receptors (i.e., surface water, groundwater aquifers and boreholes, residential areas and important ecological habitats) are identified. All identified areas should be clearly highlighted on site plans and included in the emergency plan. In many countries an incident at a lead recycling plant would be regarded as a major accident hazard and there are specific requirements regarding the preparation of emergency plans for incidents.

**Commented [CV43]:** On behalf of the consultant: Many WLAB recycling plants are covered by legislation under the Seveso Directive in Europe and they are required to have emergency response plans in place to control major accident hazards - the PW TG includes this and it was specifically mentioned in the draft index provided to the consultant.

~~331.~~344. The location and quantity of hazardous substances, (i.e., raw materials and wastes) stored, handled or produced and ~~potential~~ health, safety and environmental hazards associated with each location should be identified and clearly shown on site plans and included in the emergency plan.

~~332.~~345. Critical equipment including, but not limited to, gas cylinders, tanks and piping, containers, flexible hoses etc. and operations (e.g., tanker unloading, blockages in the wastewater system) that could cause a significant incident/release due to malfunction or abnormal conditions should be identified.

~~333.~~346. The ~~potential~~ consequences of an emergency should be identified and the risk of such an incident occurring should be assessed. Where a risk is identified adequate engineering controls to prevent or minimise the identified risks for emergency events should be established. Examples of the types of measures to be considered include:

(a) Fire/emergency alarms and firefighting equipment;

(b) Storing gas cylinders in locked cages;

(c) Locking and closing electrical distribution boxes;

(d) Spill and release detection and alarm systems;

(e) Spill diversion and retention systems;

(f) Secondary containment.

(g) Spill control kits.

~~334.~~347. To minimise the risks for key activities, such as, unloading and loading bulk tankers (e.g., fuel oil, caustic, acids, etc.) organisational controls and standard operating procedures should be developed together with identifying and obtaining the appropriate spill control equipment and other emergency equipment to be readily available in the event of an incident arising.

### 2. Emergency organization and plan

~~335.~~348. To address emergency situations each company/site should develop and establish an emergency preparedness and response plan and emergency response procedures. The plan should include:

(a) Incident notification (e.g., authorities, emergency services, management);

(b) Emergency actions;

(c) Alarm and evacuation procedures;

(d) Fire exits;

(e) Location of firefighting equipment;

(f) Emergency assembly points;

(g) Contacts details of the emergency services.

~~336.~~349. The plan should clearly define the roles, responsibilities, and staffing requirements (the Emergency Response Organisation) needed in an emergency. If an emergency response team is established, then sufficient personal protective equipment should be available and appropriate for the emergency.

~~337.~~350. Warning, notification, and communication procedures should be established which include, but are not limited to:

(a) Facility emergency staff (internal contact list);

(b) Local external emergency services (external contact list);

(c) Regulatory agencies (contact list);

(d) Communicating with the public;

(e) Media;

(f) Company management.

~~338.~~351. Copies of the emergency plan should be readily available for use by the emergency services in the event of an emergency.

### 3. Emergency response training

~~339.~~352. Each company/site should evaluate emergency training needs of all personnel assigned specific duties and roles in the emergency plan and ensure they receive adequate training. Routine training and refresher training should be provided to the emergency response staff, and tests and drills should be performed on a regular basis so that everyone is familiar with what to do in the event of an emergency. The emergency services should also be invited to attend site to familiarise themselves with the layout and ~~potential~~ issues that they may need to respond to. Response exercises should include a debriefing session to evaluate any problems and areas for improvement so that these can be corrected and updated.

### 4. Emergency plan management

~~340.~~353. A logbook to record activities taken during emergency incidents should be maintained. In the event of an incident the emergency preparedness should be reviewed and amended. Emergency response procedures should also be reviewed and updated, where appropriate, on a regular basis to ensure the plan is update and accurately reflects the hazards, risks and controls. Public participation is a core principle of the 1999 Basel Declaration on Environmentally Sound Management and many other international agreements. It is essential that the public and all stakeholder groups have a chance to participate in the development of policy related to plastic wastes, the planning of programmes, the development of legislation, the review of documents and data and decision making on local issues related to plastic wastes. Paragraphs 6 (g) and (h) of the Basel Declaration reflect an agreement to enhance and strengthen efforts and cooperation to achieve ESM regarding the enhancement of information exchange, education, and awareness-raising in all sectors of society, along with cooperation and partnership at all levels between countries, public authorities, international organizations, industry, non-governmental organizations and academic institutions.

## L. Awareness and participation

~~341.~~354. Public participation is a core principle of the 1999 Basel Declaration on Environmentally Sound Management and many other international agreements. It is essential that the public and all stakeholder groups have a chance to participate in the development of policy related to WLAB wastes, the planning of programmes, the development of legislation, the review of documents and data and decision making on local issues related to waste lead-acid batteries. Paragraphs 6 (g) and (h) of the Basel Declaration reflect an agreement to enhance and strengthen efforts and cooperation to achieve ESM with regard to the enhancement of information exchange, education, and awareness-raising in all sectors of society, along with cooperation and partnership at all levels between countries, public authorities, international organizations, industry, non-governmental organizations and academic institutions.

~~342.~~355. Articles 6, 7, 8, and 9 of the UNECE 1998 Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention), along with the Escazú Convention, require the parties to conduct fairly specific types of activities regarding public participation in specific government activities, the development of plans, policies and programmes and the development of legislation and call for access to justice for the public with regard to the environment.

~~343.~~356. Public awareness and attitudes to WLAB can affect the population's willingness to cooperate and participate in good waste management practices. General environmental awareness and information on health risks due to inappropriate waste management are important factors which need to be continuously communicated to all sectors of the population.

~~344.~~357. Raising public awareness and promoting public participation is especially critical for the environmentally sound management of WLAB.

~~345.~~358. Local authorities should organize awareness raising campaigns/events addressed to business and the public to make people aware of the importance of ESM of WLAB in tackling environmental problems such as lead pollution and in improving people's lives. There exists a variety of communication techniques that can be used, such as door to door information, leaflets, community meetings, media etc. Communication objectives could include:

(a) Emphasize health benefits;

(b) Use simple messages and multiple media types;

(c) Build on existing neighbourhood networks;

(d) Emphasize the economic and environmental benefits of proper WLAB management;

(e) Frame WLAB management activities as a topic of great interest for voters, particularly on important issues (e.g., lead pollution);

(f) Increase visibility and credibility of good WLAB management activities;

(g) Identify instances where city activities support national goals;

(h) Communicate about the national benefits of proper local waste management (e.g., to attract investments);

(i) Tailor communication to the intended audience;

(j) Emphasize the economic benefits to businesses (e.g., better conditions for attracting investment).

359. In many jurisdictions the public have access to and can participate in the process for granting/changing/updating permits/approvals. The authorities are required to make available to the public (including via the Internet) the basis of the decisions, results of consultations, details of the permit conditions, any derogations and the reasons for it, and measures taken by an operator following permanent cessation of activities. The public also have access to the legal system or another independent/impartial body for a legal review to challenge decisions/acts/omissions. Prior to any legal action being taken the authorities may have a review process/procedure.

# Bibliography


American National Standard Institute (ANSI), 2019. American National Standard for Portable Primary Cells and Batteries with Aqueous Electrolyte—Safety Standard. Available from: https://www.nema.org/docs/default-source/standards-document-library/ansi-c18-1m-part-2_2019-contents-and-scope.pdf?sfvrsn=75bd53f_0

Batteries and Energy Storage Technology (BEST), 2017. EU Fenixpb EU Grant. Available from: https://www.bestmag.co.uk/eu-grant-boost-uk-lab-recycling-research/

British Standard (BS10175), 2017. Investigation of Potentially Contaminated Sites. Code of Practice. Available from: https://knowledge.bsigroup.com/products/investigation-of-potentially-contaminated-sites-code-of-practice-code-of-practice/standard

California EPA, 2017. Fact Sheet on Lead Contamination. Available from: https://oehha.ca.gov/risk-assessment/sites

Commission for Environmental Cooperation (CEC), 2016. Environmentally Sound Management of Spent Lead-Acid Batteries in North America. Available from: http://www.cec.org/files/documents/publications/11665-environmentally-sound-management-spent-lead-acid-batteries-in-north-america-en.pdf

Custom Market Insights, 2022. Lead Acid Battery Market Size, Trends and Insights by Product and by Region – Global Industry Overview. https://indiashorts.com/latest-global-lead-acid-battery-market-size-share-worth-usd-90-billion-by-2030

Engitec Technologies. Lead Recycling. Available from: https://www.engitec.com/index.php?a_lang=en&a_name=lead

European Chemicals Agency (ECHA), 2020. Opinion on Scientific Evaluation of Occupational Exposure Limits for Lead and its Compounds. Available from: https://echa.europa.eu/documents/10162/7937606/oel_lead_final_opinion_en.pdf/1853edfa-da47-c110-106e-2a70c30cef93?t=1601555415649

European Chemicals Agency (ECHA), 2019. Scientific Report on Lead and its Compounds. Available from: https://echa.europa.eu/documents/10162/28403135/oel_lead_compounds_sci_rep_en.pdf/4ce397fa-433f-fa30-af4d-bb2c2f72549b

European Commission (EC), 2018. Study in support of evaluation of the Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators. Available from: https://ec.europa.eu/environment/pdf/waste/Published%20Supporting%20Study%20Evaluation.pdf

European Commission (EC), 2016. Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries. Available from: https://eippcb.jrc.ec.europa.eu/reference/non-ferrous-metals-industries-0

European Commission, 2014. Development of Guidance on Extended Producer Responsibility (EPR). Final Report. Available from: https://ec.europa.eu/environment/archives/waste/eu_guidance/pdf/Guidance%20on%20EPR%20-%20Final%20Report.pdf

European Commission, 2014. Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment. Available from : https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0052

European Commission (EC), 2011. Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011L0092

European Commission (EC), 2008. Directive 2008/98/EC on waste. Available from: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF

International Labour Organisation (ILO), 2001. Safety and Health in the NonFerrous Metals Industries. Available from : https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/normativeinstrument/wcms_107713.pdf

International Labour Organisation (ILO), 1990. Chemicals Convention C170. Available from : https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C170

International Maritime Organisation (IMO), 2022. The International Maritime Dangerous Goods (IMDG) Code. Available from : https://www.imo.org/en/OurWork/Safety/Pages/DangerousGoods-default.aspx

The Minerals, Metals & Materials Society, 2020. The FAST Pb Process and Its Impact on Secondary Lead Production. Available from : https://link.springer.com/chapter/10.1007/978-3-030-37070-1_50

Netherlands Public Health & Environment Ministry, 2001. Technical Evaluation of the Intervention Values for Soil/sediments and Groundwater. Available from: https://www.pbl.nl/sites/default/files/downloads/711701023.pdf

Organisation for Economic Co-operation and Development (OECD), 2019. Waste Management and the Circular Economy in Selected OECD Countries: Evidence from Environmental Performance Reviews. Available from: https://www.oecd-ilibrary.org/environment/waste-management-and-the-circular-economy-in-selected-oecd-countries_9789264309395-en

Organisation for Economic Co-operation and Development (OECD), 2016. Extended Producer Responsibility, Guidance for Efficient Waste Management. Available from: https://www.oecd.org/environment/extended-producer-responsibility.htm

Organisation for Economic Co-operation and Development (OECD), 2007. Guidance Manual for the Implementation of the OECD Recommendation on the Environmentally Sound Management of Waste. https://www.oecd.org/env/39559085.pdf#:~:text=On%209%20June%202004%2C%20the%20OECD%20Council%20adopted,Waste%20Prevention%20and%20Recycling%20%28WGWPR%29%20%28as%20of%202001%29.

Organisation for Economic Co-operation and Development (OECD), 2002. Harmonised Integrated Classification System for Human Health and Environmental Hazards of Chemical Substances and Mixtures. Available from: https://www.oecd-ilibrary.org/environment/harmonised-integrated-classification-system-for-human-health-and-environmental-hazards-of-chemical-substances-and-mixtures_9789264078475-en

Recycling Today, 2021. Aqua Metals is developing a method to streamline recycling process. Available from: https://www.recyclingtoday.com/news/aqua-metals-technology-streamlines-lead-battery-recycling/

US Department of Energy, Office of Scientific and Technical Information (OSTI), 1995. Lead-acid battery recycling by the PLACID process: A global approach. Available from: https://www.osti.gov/biblio/197296

PWC, 2020. Going Green: Recycling Contribution Fees. Available from: https://www.pwc.com.tr/en/hizmetlerimiz/vergi/bultenler/2020/going-green-recycling-contribution-fees-start-in-2020.html

Safe Work Australia, 2022. Workplace Exposure Standards for Airborne Contaminants. Available from : https://www.safeworkaustralia.gov.au/doc/workplace-exposure-standards-airborne-contaminants-2022

Sustainable Recycling Industries (SRI), 2021. Standard Operating Procedures for the Environmentally Sound Management of Used Lead-Acid Batteries. Available from: https://www.sustainable-recycling.org/wp-content/uploads/2022/04/ULAB_recycling_SOPs.pdf

UK Government. Waste: Environmental Permits. Available from: https://www.gov.uk/guidance/waste-environmental-permits

UK Government. Hazardous Waste Producer (England). Available from: https://www.gov.uk/dispose-hazardous-waste/producers-and-holders

UK Government. Hazardous Waste Producer Registration (Wales). Available from: https://www.gov.uk/hazardous-waste-producer-registration-wales

UK Government, 2017. Town and Country Planning (Environmental Impact Assessment) Regulations 2017. Available from: https://www.gov.uk/guidance/environmental-impact-assessment

UNECE, 2022 Recommendations on the transport of Dangerous Goods- Model Regulations. Available from: https://unece.org/info/Transport/Dangerous-Goods/pub/364867

UNECE, 2012. Globally Harmonized System of Classification and Labelling of Chemicals (GHS Rev. 9, 2021). Available from: https://unece.org/transport/standards/transport/dangerous-goods/ghs-rev9-2021

UNEP, 2022a. Findings and Recommendations to Improve as Appropriate the Strategic Framework for the Implementation of the Basel Convention 2012-2021. Available from : http://www.basel.int/Implementation/StrategicFramework/Improvingthestrategicframework20222023/Recommendationstoimprovethestrategicframework/tabid/9464/Default.aspx

UNEP, 2022b. Technical Guidelines Lead Paint Reformulation. https://saicmknowledge.org/sites/default/files/resources/Lead_Paint_Guide.pdf

UNEP, 2022c. Guidance Manual for Policy Makers and Regulators for the Environmentally Sound Management of Waste Lead Acid Batteries in Africa. https://wedocs.unep.org/bitstream/handle/20.500.11822/40379/ACID_BATTERIES_AFRICA.pdf?sequence=3&isAllowed=y

UNEP, 2022d. Technical guidelines on the environmentally sound disposal incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1. Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2022e Technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill (D5). Available from: http://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx

UNEP, 2022f. Practical manual for stakeholders to ensure that notifications of transboundary movements meet environmentally sound management requirements. Available from: http://www.basel.int/TheConvention/ConferenceoftheParties/Meetings/COP15/tabid/8392/Default.aspxUNEP 2019. Basel Convention, Control of Transboundary Movements of Hazardous Wastes and their Disposal. https://www.unep.org/resources/report/basel-convention-control-transboundary-movements-hazardous-wastes

UNEP, 2019. Guidance to assist parties in developing efficient strategies for achieving recycling and recovery of hazardous and other wastes (UNEP/CHW.14/INF/7). Available from: http://www.basel.int/TheConvention/ConferenceoftheParties/Meetings/COP14/tabid/7520/Default.aspx

UNEP, 2017a. Set of practical manuals for the promotion of the environmentally sound management of wastes. Available from: http://www.basel.int/Implementation/CountryLedInitiative/EnvironmentallySoundManagement/ESMToolkit/Overview/tabid/5839/Default.aspx

UNEP, 2017b. Guidance to assist Parties in developing efficient strategies for achieving the prevention and minimization of the generation of hazardous and other wastes and their disposal. Available from: http://www.basel.int/TheConvention/ConferenceoftheParties/Meetings/COP13/tabid/5310/Default.aspxUNEP, 2015b. Global Waste Management Outlook. Available from: https://www.unep.org/resources/report/global-waste-management-outlook

UNEP, 2015a. Methodological Guide for the development of inventories of hazardous wastes and other wastes under the Basel Convention. UNEP/BRS/SBC/2015/5.

UNEP, 2015b. Manual for the implementation of the Basel Convention. Available from: http://www.basel.int/Implementation/LegalMatters/Compliance/GeneralIssuesActivities/Activities201415/Manualfortheimplementation/tabid/4160/Default.aspx

UNEP, 2015c. Guide to the control system. Available from: http://www.basel.int/Implementation/LegalMatters/Compliance/GeneralIssuesActivities/Activities201415/Guidetothecontrolsystem/tabid/3561/Default.aspx

UNEP, 2013. Framework for the environmentally sound management of hazardous wastes and other wastes. Available from: http://www.basel.int/Implementation/CountryLedInitiative/EnvironmentallySoundManagement/ESMFramework/tabid/3616/Default.aspx

UNEP, 2002. Technical Guidelines for the identification and environmentally sound management of plastic wastes. Available from: http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-WAST-GUID-PlasticWastes.English.pdf

UNEP, 1995. Technical Guidelines on Specially Engineered Landfill (D5). Available from: https://digitallibrary.un.org/record/699689

United States Environmental protection Agency (US EPA). Resource Conservation and Recovery Act (RCRA) Permit. Available from: https://www.epa.gov/hwpermitting/what-hazardous-waste-permit#:~:text=All%20facilities%20that%20currently%20treat%2C%20store%20or%20dispose,they%20can%20manage%20hazardous%20waste%20safely%20and%20responsibly.

United States Department of Labor, Occupational Health and Safety Administration (OHSA), 2013. Management Guidelines for Blood leads in Adults. Available from: https://cdn.ymaws.com/www.cste.org/resource/resmgr/OccupationalHealth/ManagementGuidelinesforAdult.pdf

WCO, 2022. Harmonised System Classification Handbook. http://www.miratrans.am/myfiles/files/files/HS%20Codes.pdf

World Health Organisation (WHO), 2017. Recycling used lead-acid batteries: health considerations. Available from: https://apps.who.int/iris/bitstream/handle/10665/259447/9789241512855-eng.pdf