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Open-ended Working Group of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal
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Agenda item 3 (b) (i) c.

Matters related to the work programme of the Open-ended Working Group for the biennium 2024–2025: scientific and technical matters: technical guidelines: technical guidelines on the environmentally sound management of waste lead-acid batteries and on other waste batteries

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

Note by the Secretariat

The annex to the present note sets out a revised version of the technical guidelines on the environmentally sound management of waste batteries other than waste lead-acid batteries, as revised by the Open-ended Working Group at its fourteenth meeting. The present note, including its annex, has not been formally edited.

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Annex

Draft technical guidelines on the environmentally sound management of waste batteries other than waste lead-acid batteries [non-lead acid batteries]

Version of 27 June 2024

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Abbreviations and acronyms

Commented [MO1]: to be updated last, when the content is defined

A/C	alternating current
BAT	best available techniques
BEV	battery electric vehicles
CAS	Chemical Abstracts Service
CEN	European Committee for Standardization
D/C	direct current
EMS	environmental management system
EN	European standard
EPR	extended producer responsibility
ESM	environmentally sound management
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
GHS	Globally Harmonized System
HEV	Hybrid electric vehicles
HCl	hydrochloric acid
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICCM	International Conference on Chemicals Management
IIED	International Institute for Environment and Development
ILO	International Labour Organization
IMERC	Interstate Mercury Education and Reduction Clearinghouse
IMO	International Maritime Organization
ISO	International Organization for Standardization
LIBs	Lithium-ion batteries
MEE	Ministry of Ecology and Environment (China)
MMSD	Mining, Minerals and Sustainable Development (IIED/WBCSD project)
MSW	municipal solid waste
NEMA	National Electrical Manufacturers Association
NEWMOA	Northeast Waste Management Officials' Association
Ni-Cd	Nickel-Cadmium battery
NOx	nitrogen oxide
OECD	Organisation for Economic Co-operation and Development
OEWG	Open-ended Working Group (of the Basel Convention)
OWB	Other Waste Batteries, in the present document it refers to waste batteries other than waste lead acid batteries
PACE	Partnership for Action on Computing Equipment
PBB	polybrominated biphenyls
PBDE	polybrominated diphenyl ethers
PCB	polychlorinated biphenyl
PCDDs/PCDFs	polychlorinated dibenzodioxins/polychlorinated dibenzofurans
PHEV	Plug-in hybrid electric vehicles
PLBs	Polymer Lithium-ion batteries
PRTR	pollutant release and transfer register
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RoHS	Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive)
SAICM/GFC	Strategic Approach to International Chemicals Management/Global Framework on Chemicals and Wastes
SETAC	Society of Environmental Toxicology and Chemistry
SO_2	sulphur dioxide
SOP	standard operational 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)
WEEE	waste electrical and electronic equipment
WLAB	Waste lead acid batteries
WHO	World Health Organization

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	Liter
m^3	cubic meter
cm^3	cubic centimeter
℃	degree Celsius

I. Introduction

A. Scope

1. The present technical guidelines, pursuant to decisions BC-15/11 and BC-16/6 of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal, provide guidance on the environmentally sound management (ESM) of waste batteries other than waste lead acid batteries (WLAB)..

2. The term "other waste batteries (OWB)" is used in the present document to refer [to other waste in batteries other than lead] to waste batteries other than waste lead acid batteries[1]. [Used batteries and waste batteries are terms used interchangeably in some countries.]

Commented [FC2]: EU proposed to add an appendix to the guidelines listing country specific criteria for distinguishing between waste batteries and used batteries

3. These guidelines cover waste batteries [and some battery wastes], which are categorised as hazardous wastes or other wastes under the Basel Convention.

4. [Examples of batteries covered by the present guidelines are provided in section C.] [These are:

(a) Lithium based batteries;

(b) Nickel based batteries;

(c) Sodium based batteries;

(d) Alkaline and Zinc batteries;

(e) [Mixed batteries];

(f) Other type of batteries].

5. It should be noted that several other technical guidelines also provide guidance on other [battery wastes] (OWB), as follows:

(a) [For specific guidance on OWB containing or contaminated with persistent organic pollutants (POPs), see the Basel Convention general technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with Persistent Organic Pollutants (UNEP, 2023a) and the Basel Convention specific technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with hexabromodiphenyl ether and heptabromodiphenyl ether, or tetrabromodiphenyl ether and pentabromodiphenyl ether or decabromodiphenyl ether (UNEP, 2019b);]

(b) For specific guidance on the incineration of OWB, see the technical guidelines on the environmentally sound incineration of hazardous wastes and other wastes as covered by disposal operations D10 and R1 (UNEP, 2022d);

(c) [For specific guidance on the landfilling of OWB, see the technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill (D5) (UNEP, 2022e);]

(d) For specific guidance on plastic in OWB, see the technical guidelines on the environmentally sound management of plastic wastes (UNEP, 2023b);

(e) For specific guidance on the recycling/reclamation of metals and metal compounds in OWB, see the technical guidelines on the environmentally sound recycling/reclamation of metals and metal compounds (R4) (UNEP, 2004);

(f) For specific guidance on mercury waste, see the technical guidelines on environmentally sound management of mercury waste;

(g) For specific guidance on environmentally sound management of waste lead acid batteries see the related technical guidelines.

6. The definition of hazardous and other wastes under the Basel Convention and the entries in the Annexes of the Convention, related to waste batteries in the scope of these guidelines are described in section II A of the present document.

[1] [Used batteries and waste batteries are terms used interchangeably in some countries.]

B. About batteries and [waste batteries] [battery wastes] in these guidelines (hereinafter referred to as batteries and waste batteries)

7. Batteries are an important source of energy and it is expected that the demand for batteries will grow rapidly in the coming years for electric road transport vehicles, light means of transport and for the storage of energy produced by discontinuous renewable sources. It is necessary to provide clear indication on the sounds management of waste batteries in order to take measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste, by improving their recyclability and resource efficiency.

8. Batteries are energy containers, not inanimate objects, they must be managed appropriately during their useful life and during transport to ensure that they can provide energy in the places and ways required, based on the characteristics desired by the designer and according to the needs of the user. Likewise, appropriate measures must be taken to ensure that the residual energy and chemical substances present in the battery at the end of its life do not pose hazards for people and the environment.

9. Many types of batteries have been developed, different in chemical composition, shape and size to meet the different needs of use: alone or in equipment, on land, in the sea and in the air, in temperate or extreme climate zones, for this reason drawing up these technical guidelines is particularly challenging, also considering the continuous evolution of the sector where research and development activities continually bring new types of batteries onto the market.

10. A battery consists of one or more cells that can undergo a chemical reaction that generate electricity and their chemistry can determine characteristics that make its application particularly suitable in specific sectors; there is no "one" battery suitable for all situations, each type is better suited than others in particular applications or markets, as briefly explained below:

11. Lithium-ion Batteries are used in many electrical and electronic equipment, among other uses, batteries are important components of portable electrical and electronic devices. For example, the use of the lithium-ion batteries (LIBs) in portable electronic devices, such as mobile phones, laptop, cameras, toys, e-cigarettes, and electric and garden tools, has doubled from 2014 to 2019 (Mossali 2020). The LIB has been used widely for a wide range of applications because of its high performance in a number of important functional criteria, e.g., battery life, high storage capacity, small size, low mass, efficient self-discharging capacity to withstand different climatic and temperature environments.

12. Nickel batteries are based on the Nickel electrochemistry, they include Nickel–cadmium (Ni-Cd) batteries and Nickel Metal Hydride batteries (NiMH). Ni-Cd offer robust cycle life (>2000 cycles), high power delivery, tolerance to overcharging/deep discharging, and operation at low temperatures. Ni-MH batteries are an improvement over Ni-Cd batteries while, at the same time, eliminating the use of toxic cadmium; they offer good high-temperature tolerance, lower self-discharge than NiCd, good tolerance to over- charge/discharge.

13. Sodium batteries, based on the Sodium electrochemistry, are represented by the consolidated high temperature batteries characterized by the presence of liquid sodium (Zebra batteries and Sodium-Sulphur batteries) and by an innovative battery, the Sodium-ion battery, similar in design and construction to Lithium ion batteries but relying on sodium compounds rather than lithium; sodium is far more abundant and more sustainable to extract and refine than lithium, costs should be lower and the flammability of the electrolyte has already resulted in its classification as dangerous good for transportation.

14. Alkaline and Zinc batteries are non-rechargeable (primary) batteries widely used where an immediately available portable energy source is needed and where it is not possible to recharge other types of batteries. Alkaline batteries contain certain Zn- and Mn-compounds; batteries like Zinc carbon (Zn-C), Zinc Chloride (Zn-Cl), Zinc-air are commonly named Zinc based batteries. They are often used in low-drain devices, such as battery-operated toys and remote controls.

15. Among waste batteries we need to consider two other types of battery wastes:

(a) “Manufacturing Waste”, it the material rejected during the battery manufacturing process;

(b) “Black Mass”, it is the powder obtained from the mechanical crushing of batteries during pre-treatment of waste batteries.

16. Both wastes are marketed for recycling in sites other than those of production and are relevant to recover fundamental metals and compounds used to produce new batteries. Their characteristics are described in section H.3.(f) and H.2.iii respectively.

17. This guide provides useful information on the transport, as most of them are classified as dangerous goods, treatment and recycling activities of waste batteries at the end of their life in an environmentally sound manner to safeguard the health of people and the environment.

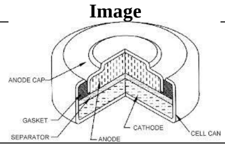
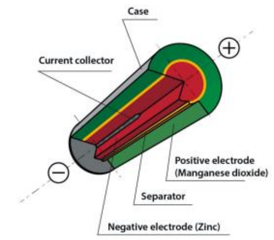
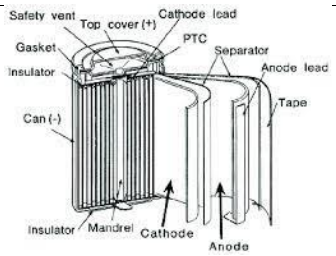
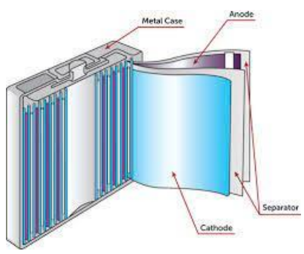
18. To give just one example, only 30% to 50% of the world population properly dispose of portable LIBs, being unaware of the potential harmfulness of post-use products. A possible consequence could be fires generated in waste treatment plants, where the presence of humidity and flammable electrolytes can generate explosive reactions and the emission of harmful gases (such as hydrogen fluoride) in case of mechanical damage, overheating or degradation phenomena, exposing people to the risk of serious injury (Mossali 2020). [ITU-T L1035].

19. This guideline does not provide information for the management of waste lead-acid batteries, for which please refer to the specific guidelines: Technical guidelines on the environmentally sound management of waste lead-acid batteries.

C. Categories and types of batteries

20. Batteries are commonly classified according to various criteria, for example: the electrochemical process that generates electricity, the shape, the rechargeability, the composition, the size, the application; an overview follows.

1. The shape of cells

Cell shape	Image
Button cell (or coin cells) *Cells having diameter larger than height*	
Cylindrical (Zn-C, alkaline)	
Cylindrical (lithium ion)	
Prismatic (lithium ion)	

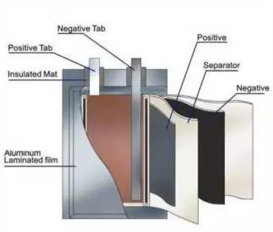
Cell shape	Image
Pouch (lithium ion)	

Table 1: The shape of cells

2. Rechargeability: primary and secondary batteries

(a) Primary batteries (non-rechargeable)

21. The chemical reaction inside the battery that produces electricity is not reversible, the battery is not rechargeable and needs to be recycled once all chemical energy has been converted into electrical energy and consumed. Batteries commonly used in application where long shelf life, portability and low self-discharge are critical, examples are zinc-based technologies such as alkaline manganese and zinc carbon, but also most of the lithium metal chemistry is not rechargeable.

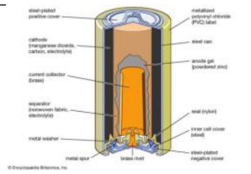
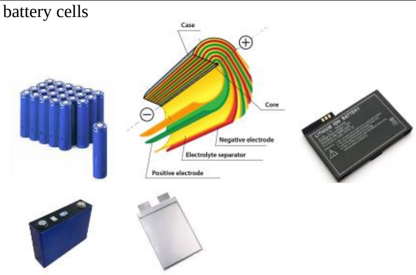
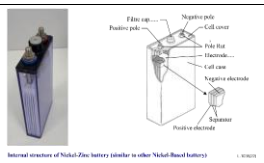
Type	Image/Example	Applications
Button cells -silver-oxide - zinc-air - lithium metal		Watches, calculators, novelty greeting cards, laser pointers, hearing aids, car unlock remote control
Alkaline		MP3 players, CD players, digital cameras, toys, lights, and radios
Lithium Tyonil-Chloride		measurement systems, meters and data loggers

Table 2: Primary batteries

(b) Secondary batteries (rechargeable)

22. The chemical reaction inside the battery that produces electricity is reversible, the battery can be recharged via the input of electricity and used repeatedly. They are widely used in applications that require higher energy densities and longer operational lifetimes. The available capacity might deteriorate over time, but this depends on the chemical system, the use and charging patterns. Examples are lithium-ion batteries as well as sodium-based and nickel-based batteries. (ITU-T L1035).

Type	Image/Example	Applications
Lithium-ion	battery cells 	Power tools, ICT basic elements for assembling battery packs and battery modules
	battery pack 	Power tools, ICT, Light means of transport
	battery modules  cylindrical cells prismatic cells pouche cells	Electric vehicle, electric mobility, power tools, UPS, ICT, peak reduction and load shifting, storage systems
Nickel - Cadmium	  sealed dry cell wet, cells and batteries	UPS, special applications, peak reduction and load shifting
Nichel-Metal Hydride	  sealed dry cell wet, cells and batteries	Power tools, ICT, HEV
Nickel-Zinc	 wet, cells and batteries	UPS, special applications, peak reduction and load shifting
Sodium- Nickel Chloride (ZEBRA)	 sealed cells and batteries	Peak and load shift reduction, frequency and voltage regulation

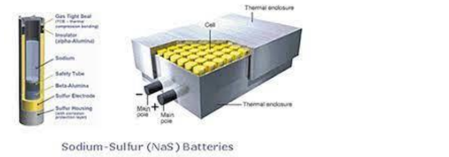
Type	Image/Example	Applications
Sodium-Sulphur	 sealed cells and batteries	Peak and load shift reduction, frequency and voltage regulation

Table 3: ~~Non r~~Rechargeable batteries

3. The modular structure of the batteries

(a) Cells, batteries, modules, battery packs, battery systems, BESS

23. It is important to note that lithium- and sodium-based batteries, and partly also nickel-based ones, have an assembly system that allows the individual cells to be connected together to create modules and packs with which to create Battery Systems where electronic circuits called Battery Management System (BMS), they regulate the voltage and the passage of current during the discharge and recharge phases. Battery Systems can also be equipped with cooling circuits, as illustrated in the following figure:

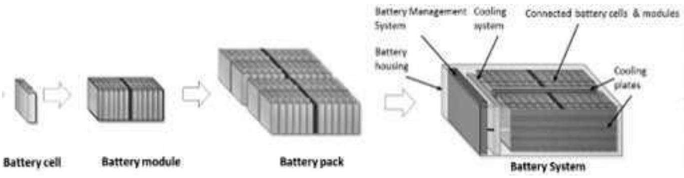


Figure 1: Assembly systems of batteries

24. The need to have large quantities of energy in systems dedicated to plant safety or in emergency systems such as UPS (Uninterruptable Power Supplies) for hospitals or data centers can be implemented connecting battery modules on racks, governed by Inverters and charging systems.

25. The need to have large quantities of energy in remote places and the possibility to transport them easily without having to dismantle them, has generated what are commonly called BESS: Battery Energy Storage System.

Figure 2: Battery Energy Storage System (BESS)

26. Inside these containers are contained the batteries and all the instrumentation necessary to manage the power supply, the discharge-charge cycles, thermal conditioning systems and safety systems.

27. The dismantling of these BESSs at the end of their life would entail the need to follow the reverse path followed in the assembly phase of the new BESS, with the separation of the individual modules until thousands of cells are obtained to be recycled.

Figure 3: Steps for the dismantling of batteries BESS. Source: *Guida Introduttiva ANIE CSI alle Batterie: Mercato, Tecnologie, Applicazioni (2023)*[2]

4. Categorization of batteries, based on their use

28. To optimize end of life battery collection operations it is necessary to know which applications they were designed for, where they are used and how they are marketed, which is why it is important to have a categorization of batteries based on their use, in this way is possible to identity the most effective waste stream for collection and the subsequent treatment and recycling processes can start in a homogeneous and efficient way.

29. Batteries are usually identified as automotive, batteries for electric vehicles, for light mobility transport, for portable applications and communication technology (ICT), industrial batteries for energy storage and stationary application such as servers, data centres, radio towers, etc.

Electric vehicle batteries (EV)	Batteries designed for the propulsion of vehicles	BEV cars
		BEV buses & trucks
		BEV motorcycles
		PHEV cars
		PHEV buses & trucks
		HEV cars
Light Means of Transport batteries (LMT)	Batteries designed for the propulsion of light electric wheeled vehicles, also in combination of human power.	e-bikes
		e-Scooters
		Hoverboard
		Monowheels
Automotive batteries	Batteries designed to supply electric power for Starting, Lighting,	Cars with Internal Combustion Engines

[2] Federation of Italian Electric and Electronic Industries - anie.it.

(SLI)	Ignition and/or for Auxiliary functions	Auxiliary or backup purposes in vehicles, other means of transport or machinery
Portable batteries	Battery not designed for EV, LMT, SLI or Industrial use	Cellphones
		Cameras
		Consumer electronics (portable PC, games, tablet, etc..)
		Power tools
		Power Banks
Industrial batteries	Battery designed for industrial uses, including stationary battery for energy storage systems (BESS)	Electricity supply: back-up power systems and load levelling for grid supply networks
		Renewable energy storage
		Emergency services: back-up power systems
		Large-scale Uninterrupted Power Supply (UPS) systems
		Telecommunications systems:
		Street Lighting
		Desktop UPS systems
		Renewable energy storage systems
		Back-up power systems
		Back-up power for security systems

Table 4: Categorization of batteries based on their use. Source:

5. Categorization of batteries based on composition

30. Closely linked to their application and use is the performance characteristic of the battery, i.e. its ability to store energy, deliver an electric current and maintain it over time. The different chemistries are able to provide different performances, in order to compare them we relate to the unit of weight (kg) so that they can be measured in Specific Power (W/kg) and in Specific Energy (Wh/kg) and represented in the following figures[3]:

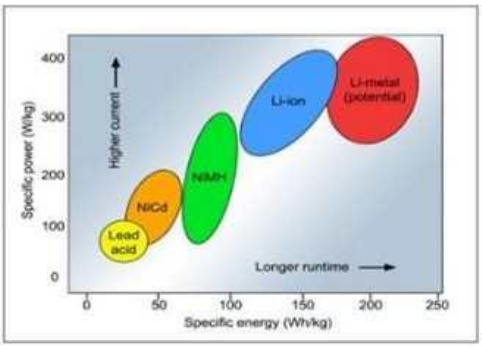


Figure 4: Specific energy of batteries.

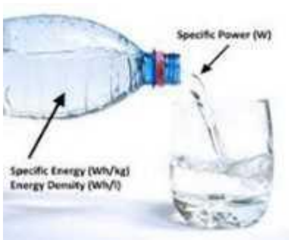


Figure 5: Battery specific energy. Source:

[3] Battery University.

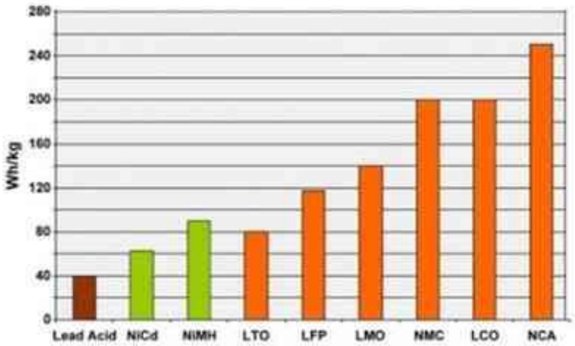


Figure 6: Specific energy of various batteries compositions. Source

31. The choice of the designer and the user will fall on the battery capable of giving the best performances in the instrument or application it needs to power, which will last longer over time, which will be able to perform the greatest number of cycles, which will need less time to recharge and at the most convenient cost; there are multiple solutions, which we will illustrate in this chapter.

32. At their end of life, batteries must be collected and sorted according to their composition in order to optimize the subsequent treatment and recycling phases. We can group batteries in the following way based on their main constituents, their composition and the treatment and recycling processes they will undergo at the end of their life.

(a) Lithium based batteries:

(i) Lithium metal;

(ii) Lithium-ion;

(iii) Lithium solid state;

(b) Nickel based batteries:

(i) Nickel-Iron (NiFe);

(ii) Nickel Zinc (NiZn);

(iii) Nickel Cadmium (NiCd);

(iv) Nickel Metal Hydride (NiMH);

(c) Sodium based batteries:

(i) Sodium ion;

(ii) High Temperature Sodium Nickel Chloride (NaNiCl);

(iii) High temperature Sodium Sulphur (NaS);

(d) Alkaline and Zinc batteries;

(e) [Mixed batteries];

(f) Other types of batteries.

(a) Lithium based batteries

33. Due to the demand and availability of new electronic devices, tonnes of functional LIBs have been ~~discharged~~disposed. It is anticipated that 11 Mt of end-of-life LIBs will be produced cumulatively by 2030. The flows of waste LIBs from portable electrical and electronic devices will be augmented by waste LIBs employed in electric vehicles (EVs), with their annual waste flow reaching 340 000 t by 2040 (Chandran 2021). Because of their use in EVs, the projected requirement for LIBs is enormous, and this may lead to risk of short supply in the trade market due to the natural supply limitations of lithium metal resources and other raw materials.

34. It is anticipated that the call for lithium carbonate will rise from 265 000 t in 2015 to 498 000 t in 2025. This may create a gap between demand for lithium against market supplies that ultimately

may lead to a price hike of lithium carbonate. To address the risk of short supply and to reduce the cost of production, it appears crucial to recover lithium metal from all potential resources (Mohanty 2021).

35. Only 30% to 50% of the world population properly dispose of portable LIBs, being unaware of the potential harmfulness of post-use products. Metallic lithium, resulting from incorrect recycling [management] of LIBs, is highly reactive with moisture, and in the presence of a flammable electrolyte can generate explosive reactions and the emission of harmful gases (such as hydrogen fluoride) in case of mechanical damage, overheating or degradation phenomena, exposing people to the risk of serious injury (Mossali 2020). [ITU-T L1035].

(i) Lithium metal batteries

36. Lithium metal batteries are primary batteries that have metallic lithium as an anode. Most lithium metal batteries are non-rechargeable. However, rechargeable lithium metal batteries are also [available] under development.

37. They stand apart from other batteries in their high charge density and high cost per unit. Depending on the design and chemical compounds used, lithium cells can produce voltages from 1.5 V (comparable to an alkaline battery) to about 3.7 V.

38. Disposable primary lithium batteries must be distinguished from secondary lithium-ion or a lithium-polymer, which are rechargeable batteries. Pure lithium will instantly react with water, or even moisture in the air; the lithium in lithium-ion batteries is a less reactive compound.

39. Lithium batteries are widely used in portable consumer electronic devices, also as button cells. The term "lithium battery" refers to a family of different lithium-metal chemistries, comprising many types of cathodes and electrolytes but all with metallic lithium as the anode. The battery requires from 0.15 to 0.3 kg of lithium per kWh. As designed these primary systems use a charged cathode, that being an electro-active material with crystallographic vacancies that are filled gradually during discharge.

40. The most common type of lithium cell used in consumer applications uses metallic lithium as the anode and manganese dioxide as the cathode, with a salt of lithium dissolved in an organic solvent as the electrolyte. [4]

(ii) Lithium-ion batteries

41. In batteries, lithium-ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. LIBs use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode. The typical composition of LIBs, net of the variability due to different manufacturers, consists of two electrodes wound by lamination to a polymeric separator and impregnated by a suitable electrolyte, allowing ionic conductivity of lithium-ions. Due to the intrinsic properties of materials, LIBs operate between 1.5 and 4.2 V: a lower voltage degrades the copper (Cu) foil, while a higher one forms reactive lithium dendrites increasing the potential safety hazards of the product. Besides the active material of electrodes, fundamental LIB components are the highly dielectric solvent allowing the transfer of lithium-ion, the polymeric separator preserving electrodes from direct contact and copper and aluminium (Al) current collector foils, on which active powder is adhered through an organic binder (Mossali).

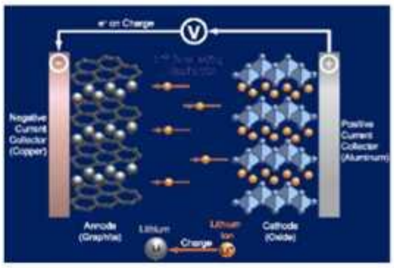


Figure 7: Chemistry of a Lithium-ion battery

[4] https://en.wikipedia.org/wiki/Lithium_metal_battery.

42. The batteries have a high energy density, no memory effect (other than LFP cells) and low self-discharge. They can, however, be a safety hazard since they contain flammable electrolytes, and if damaged or incorrectly charged can lead to explosions and fires. Chemistry, performance, cost and safety characteristics vary across types of LIB.

Figure 8: Material composition by battery type

43. Handheld electronics mostly use lithium polymer batteries (with a polymer gel as electrolyte), an LCO (LiCoO2) cathode material, and a graphite anode, which together offer a high energy density. LFP (LiFePO4), LMO (LiMn2O4 spinel, or Li2MnO3- based lithium-rich layered materials, e.g., lithium- and manganese-rich-NMC (LMR-NMC)), and NMC (LiNiMnCoO2) may offer longer lives and may have better rate capability. Such batteries are widely used for electric tools, medical equipment, and other roles. NMC and its derivatives are widely used in electric vehicles (EVs). [b-W-LIB].

Battery components	**LCO, LMO, NMC, NCA**	**LTO**	**LFP**	**LiSOCl**
	Weight (% total battery)			
Cathode material	20-50	20-50	20-50	3.5-5
Cathode current collector	8-15	6-8	6-8	no data
Anode material	10-30	10-30	10-30	3-5
Anode current collector	7	10-12	10-12	no data
Electrolyte	10-20	10-20	10-20	25-50
Binder	1-8	1-8	1	no data
Separator	3-5	3-5	3-5	3-5
Case and tab	15-30	15-30	15-30	15-30

Table 5: Variability of the main battery components for the different lithium battery chemistries under scope[5]

Battery chemistry	**Chemical compound**	**CAS No.**
LCO	LiCoO2	12190-79-3
NMC	LiNixMnyCozO2[30]	various CL entries considering the elemental composition[31]
LMO	LixMnyO4	12057-17-9
NCA	LiNixCoyAlzO2	177997-13-6; 193214-24-3
LTO	Li2TiO3	12031-82-2

[5] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

Battery chemistry	Chemical compound	CAS No.
LiSOCl	LiSOCl	not found*
LPF	LiFePO4	15365-14-7

Table 6: Overview on cathode materials for different commercial LIB composition[6]

44. Lithium batteries as e.g. LCO, LMO, NMC, NCA and LTO contain organic electrolytes, usually in the form of lithium salts dissolved in a mixture of organic solvents. The most commonly used lithium salts are LiPF6, LiBF4 and LiClO4. The organic solvents for example are in the form of ethylene-, propylene-, or dimethyl carbonate. The essential components of the lithium iron phosphate batteries (LFP) are identical to the electrolytes of other lithium batteries (Das, Manna, and Puravankara 2023; Sobianowska-Turek et al. 2021; Zackrisson and Schellenberger 2020).

Chemical compound	Lithium salts	CAS No.
LiPF6	Lithium Hexafluorophosphate	21324-40-3
LiBF4	Lithium Tetrafluoroborate	14283-07-9
LiClO4	Lithium Perchlorate	7791-03-9
	Organic solvents	
C3H4O3	Ethylene carbonate	96-49-1
C4H6O3	Propylene carbonate	108-32-7
(CH3O)2CO	Dimethyl carbonate	616-38-6
C3H2O3	Vinylene Carbonate	872-36-6
C6H5F	Fluorobenzene	462-06-6
LiF2PO2	Lithium phosphorodifluoridate	24389-25-1
F2LiNO4S2	Lithium bis(fluorosulfonyl)imide	171611-11-3
C3H6O3S	1,3-Propanesultone	1120-71-4
C8H12Si	Tetravinylsilane	1112-55-6
C2H4O4S	1,3,2-Dioxathiolane 2,2-dioxide	1072-53-3

Table 7: An example composition of electrolyte used in lithium batteries[7]

45. One of the most widely used binder in lithium batteries is made of polyvinylidene fluoride (PVDF). This binder dissolves usually in an organic solvent such as N-methyl-2-pyrrolidone (NMP). Carboxy methyl cellulose (CMC) is another well-known binder in an aqueous solvent (Das, Manna, and Puravankara 2023). Further known are Na-alginate, polyacrylic latex (LA132), Poly(acrylic acid) (PPA), poly(diallyldimethylammonium) (PDADMA) that are all applied in an aqueous solvent..[8]

46. Certain substances related to PFAS are essential parts of batteries and according to (RECHARGE 2021) only fluoropolymers are used in the battery industry. More specifically, fluorinated binders offer a higher stability due to their resistance to oxidation compared to non-fluorinated binders. These binders can also prevent self-discharge by inhibiting some electrochemical reactions and thus improve the energy density as well as lifespan of the battery[9] .

47. Electrochemical processes during the use of lithium batteries might also cause the formation of toxic chemicals e.g. in the electrolyte. The electrolyte dissociates into lithium fluoride (LiF) and phosphorus pentafluoride (PF5), which reacts with moisture and forms hydrogen fluoride (HF) and phosphoryl fluoride (OPF3). HF can represent a high environmental and health risks due to the high acute toxicity, e.g. in case of cell damage (leakage) or during end-of-life processing (Weber et al. 2014; Zackrisson and Schellenberger 2020).

$$LiPF_6\ (s) \rightleftharpoons LiF\ (s) + PF_5\ (g)$$

$$LiPF_6 + H_2O \rightleftharpoons LiF + 2HF + POF_3$$

$$PF_5 + H_2O \rightleftharpoons 2HF + POF_3$$

Figure 9: Chemical reactions in the electrolyte

Chemical compound		CAS No.
LIF	Lithium fluoride	7789-24-4
PF5	Phosphorus pentafluoride	7647-19-0
HF	Hydrogen fluoride	7664-39-3

[6] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[7] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[8] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[9] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

Chemical compound		CAS No.
POF3	Phosphoryl fluoride -	-

Table 8: Chemical compounds that are formed during electrochemical processes in lithium batteries[10]

48. In case of short circuit, elevated temperatures, impact and other abuse, thermal runaway can occur (Si, Liu, and Xue 2018). The rapid release of energy leads to the combustion of the electrolyte and, further on, other battery components. In case the battery cell breaks, lithium compounds react with the air causing an intense oxidation that promotes fire or even explosions that are difficult to extinguish. [11]

49. In late 2013, smelters started to report increased numbers of LIBs mixed with lead-acid, especially in starter batteries. This can cause fires, leading to explosion and personal injury. The physical appearance of lead-acid and lithium-ion packs are similar and sorting at high volume poses a challenge. As more lead-acid batteries are replaced with lithium-ion, the problem will only escalate. From 2010 to 2013, there has been a 10-fold increase in reported incidents of infiltration of lithium-ion with lead-acid. Lithium-ion is more volatile when stripped than lead-acid. Pre-sorting is done for safety reasons: lead is highly toxic, lithium-ion is explosive. (ITU-T L.1035 (02/2022).

50. In accordance with the standard IEC 62902:2019 Secondary cells and batteries - Marking symbols for identification of their chemistry the coding of rechargeable batteries is proposed using a combined system of colors and chemical symbols with the aim of making them immediately identifiable during separation as waste, the individual electrochemistry. Thanks to the proposed coding, the recycler will therefore be able to carry out a rapid subdivision, sending the different types of batteries to the appropriate treatment procedures.

Figure 10: Labels by battery chemistry

51. Recently, thin film prismatic polymer lithium-ion batteries (PLBs) using polymer gel electrolytes have been developed for some portable electronic appliances [1-3]. PLBs have the advantages of thinness and light weight due to the use of the laminated film bag. However, PLBs have some problems and their performance are inferior in some respects to those of other LIBs. (Takahisha).

52. Recently, graphene-based nanomaterials were successfully employed for the lithium-ion battery applications because of their superior features such as their light weight large working potential, relatively high energy density, great recharge ability and low self-discharge (Rustem)

53. Graphene and graphene-based nanomaterials which have porous structures are widely preferred for the lithium-ion battery applications since these unique nanomaterials provide facile transport of electrons and ions in the electrode materials of the lithium-ion batteries. To provide the power for the needs of the novel devices and applications, it is required to upgrade lithium-ion batteries in terms of their reliability and performance. (Rustem).

54. Various types of transition metal oxides (i.e. tin, nickel, iron, and copper) were efficiently combined with graphene to develop novel and high-performing electrode materials for lithium-ion batteries (ibidem).

(iii) Solid State batteries[12]

55. Much R&D is being done with different solid-state electrolytes, such as inorganic oxide-based and sulphide-based electrolytes, as well as polymer and composite solid electrolytes. Each type of solid-state electrolyte has challenges to reach technology maturity and no clear market dominance and winning technology can be observed yet.

56. The current Li-ion uses a graphite anode and this reduces the specific energy. Solid-state technology replaces graphite with pure lithium and substitutes the liquid electrolyte soaked in a porous separator with a solid polymer or a ceramic separator.

[10] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[11] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[12] Battery University (BU-212 Future batteries).

57. Solid-state batteries promise to store twice the energy compared to regular Li-ion, but the loading capabilities might be low, making them less suited for electric powertrains and applications requiring high currents. Targeted applications are load levelling for renewable energy source as well as EVs by cashing in on the short charge times that this battery allows. Research laboratories, including Bosch, predict that the solid-state battery might become commercially available by 2020 and be implemented in cars in 2025.

58. Solid-state batteries tend to have high internal impedance, have poor low-temperature performance and are subject to dendrite growth.

(b) Nickel based batteries

55. Nickel based batteries most commonly used are:

(a) NiFe;

(b) NiZn;

(c) Ni-Cd;

(d) Ni-MH.

(i) NiFe

59. The nickel-iron battery (NiFe) uses an oxide-hydroxide cathode and an iron anode with potassium hydroxide electrolyte that produces a nominal cell voltage of 1.20V. NiFe is resilient to overcharge and over-discharge and can last for more than 20 years in standby applications. Resistance to vibrations and high temperatures made NiFe the preferred battery for mining in Europe. Other uses are railroad signaling, forklifts and stationary applications.

60. NiFe has a low specific energy of about 50Wh/kg, has poor low-temperature performance and exhibits high self-discharge of 20–40 percent a month. This, together with high manufacturing cost, prompted the industry to stay faithful to lead acid.

61. Improvements are being made, and NiFe is becoming a viable alternative to lead acid in off-grid power systems. Pocket plate technology lowered the self-discharge; the battery is virtually immune to over- and under-charging and should last for over 50 years. This compares to less than 12 years with deep cycle lead acids in cycling mode. NiFe costs about four times as much as lead acid and is comparable with Li-ion in purchase[13]

(ii) NiZn

62. Nickel-zinc is similar to nickel-cadmium in that it uses an alkaline electrolyte and a nickel electrode, but it differs in voltage; NiZn provides 1.65V/cell rather than 1.20V, which NiCd and NiMH deliver. NiZn charges at a constant current to 1.9V/cell and cannot take trickle charge, also known as maintenance charge. The specific energy is 100Wh/kg and can be cycled 200–300 times. NiZn has no heavy toxic materials and can easily be recycled. Some packaging is available in the AA cell format.[14]

(iii) Nickel–cadmium batteries (Ni–Cd batteries)

89. The nickel–cadmium batteries (Ni–Cd batteries) are rechargeable batteries with nickel oxide-hydroxide and metallic cadmium as electrodes..

63. Wet-cell nickel–cadmium batteries were invented in 1899. A Ni–Cd battery has a terminal voltage during discharge of around 1.2 volts which decreases little until nearly the end of discharge. The maximum electromotive force offered by a Ni–Cd cell is 1.3 V. Ni–Cd batteries are made in a wide range of sizes and capacities, from portable sealed types interchangeable with carbon-zinc dry cells, to large, ventilated cells used for standby power and motive power. Ni-Cd batteries offer robust cycle life (>2000 cycles), high power delivery, tolerance to overcharging/deep discharging, and operation at low temperatures.

64. Sealed Ni–Cd cells were at one time widely used in portable power tools, photography equipment, flashlights, emergency lighting, hobby RC, and portable electronic devices. The superior capacity of nickel–metal hydride batteries, and recent lower cost, has largely supplanted Ni–Cd use. Further, the environmental impact of the disposal of the toxic metal cadmium has contributed considerably to the reduction in their use. They are commonly used in power tools, emergency lighting, radio-controlled toys/models, and cordless appliances, and they have a specific energy of 30-

[13] Battery University (BU-203 Nickel-based battteries).

[14] Battery University (BU-203 Nickel-based battteries).

80 Wh/kg. Within the European Union, Ni–Cd batteries are being phased out in the European Union can now only be supplied for replacement purposes or for certain types of new equipment such as medical devices. Larger ventilated wet cell Ni–Cd batteries are used in emergency lighting, standby power, and uninterruptible power supplies and other applications[15].

65. The Ni-Cd batteries, when fully charged, contain:

(a) a nickel(III) oxide-hydroxide positive electrode plate;

(b) a cadmium negative electrode plate;

(c) a separator; and

(d) an alkaline electrolyte (potassium hydroxide).

66. The chemical reactions at the electrodes during discharge are:

$Cd+2OH^{-} \rightarrow Cd(OH)_{2}+2e^{-}$

67. The reactions at the nickel oxide electrode are:

$2NiO(OH)+2H_2O+2e^- \rightarrow 2Ni(OH)_2+2OH^-$

68. The net reaction during discharge is:

$2NiO(OH)+Cd+2H_2O \rightarrow 2Ni(OH)_2+Cd(OH)_2$.

(iv) Ni-MH Nickel Metal hydride batteries

69. A nickel metal hydride battery (NiMH or Ni-MH) is a type of rechargeable battery. The chemical reaction at the positive electrode is similar to that of the nickel-cadmium cell (NiCd), with both using nickel oxide hydroxide (NiOOH). Nickel-metal hydride (Ni-MH) batteries are an improvement over Ni-Cd batteries, the negative electrodes use a hydrogen-absorbing alloy instead of cadmium. NiMH batteries can have two to three times the capacity of NiCd batteries of the same size, with significantly higher energy density, although only half of lithium-ion batteries. NiMH batteries offer good high-temperature tolerance, lower self-discharge than NiCd, good tolerance to over- charge/discharge, and offer a higher specific energy of 40–120 Wh/kg.

70. They are typically used as a substitute for similarly shaped non-rechargeable alkaline batteries, as they feature a slightly lower but generally compatible cell voltage, and are less prone to leaking.

a. Electrochemistry

71. The negative electrode reaction occurring in a NiMH cell is

$H_2O + M + e^- \rightleftharpoons OH^- + MH$

72. On the positive electrode, nickel oxyhydroxide, NiO(OH), is formed:

$Ni(OH)_2 + OH^- \rightleftharpoons NiO(OH) + H_2O + e^-$

73. The reactions proceed left to right during charge and the opposite during discharge. The metal M in the negative electrode of a NiMH cell is an intermetallic compound. Many different compounds have been developed for this application, but those in current use fall into two classes. The most common is AB5, where A is a rare-earth mixture of lanthanum, cerium, neodymium, praseodymium, and B is nickel, cobalt, manganese, or aluminium. Some cells use higher-capacity negative electrode materials based on AB2 compounds, where A is titanium or vanadium, and B is zirconium or nickel, modified with chromium, cobalt, iron, or manganese.

74. NiMH cells have an alkaline electrolyte, usually potassium hydroxide. The positive electrode is nickel hydroxide, and the negative electrode is hydrogen in the form of an interstitial metal hydride. Hydrophilic polyolefin nonwovens are used for separation[16].

75. Battery components of nickel-metal hydride batteries, their chemical compounds and the percentual share on the total battery mass[17].

Battery component	**NiMH**	
	Compound	Weight (% total battery)
Cathode	NiO(OH2)	15-25

[15] https://en.wikipedia.org/wiki/Nickel%E2%80%93cadmium_battery.

[16] E. Lemaire-Potteau, ... S. Genies, in Encyclopedia of Electrochemical Power Sources, 2009.

[17] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

Cathode plate	Ni foam	no data
Anode	Metal hydride alloy to e. g. AB5 (rare- earth mixture of A is lanthanum, cerium, neodymium, praseodymium, and B is nickel, cobalt, manganese, or aluminium (e.g. La0.8Nd0.2Ni2.5Co2.4Si0.1)	25-45
Anode plate/foil	Ni plated steel	no data
Electrolyte	KOH, NaOH	5-15
Separator	Polyolefin	5
Other	-	-
Case and tab	Steel, plastic	30-35

Table 9: NiMH battery components

Chemical compound	**NiMH**	**CAS No.**
NiO(OH2)	Nickel oxide hydroxide	12026-04-9
ABS	Metal hydride alloy	not found
KOH	Potassium hydroxide	1310-58-3
NaOH	Sodium hydroxide	1310-73-2

Table 10: Chemical compounds of NiMH batteries[18]

(c) Sodium based batteries

(i) Sodium ion batteries (Na-ion)

76. Sodium-ion represents a possible lower-cost alternative to Li-ion as sodium is inexpensive and readily available. Put aside in the late 1980s in favor of lithium, Na-ion has the advantage that it can be completely discharged without encountering stresses that are common with other battery systems. Some cells have 3.6V, and the specific energy is about 90Wh/kg. Further development will be needed to improve the cycle count and solve the large volumetric expansion when the battery is fully charged.

(ii) High Temperature Sodium Nickel Chloride (NaNiCl)

77. This molten salt battery is based primarily on sodium metal chemistry. A ZEBRA[19] battery contains the two electrolytes NaAlCl4 and the so called BASE, a ceramic electrolyte. The NaAlCl4 is formed by sodium chloride (NaCl) and aluminium chloride (AlCl3) at the operational temperature of the battery. This electrolyte is also called molten salt electrolyte. According to (Trickett 1998) ZEBRA batteries can also contain small amounts (< 1 %) of sodium fluoride (NaF) and iron or nickel sulphide (Ni3S2). The chemical compositions as well their percentual share on the total battery mass of the two nickel-based battery types is given in the following table (Nikolic et al. 2023).

Battery component	**Na-NiCl2 (ZEBRA battery)**	
	Compound	Weight (% total battery)
Cathode	NiCl2, NaCl, Ni (metallic)	30-40
Cathode plate	Aluminium	no data
Anode	Liquid sodium (Na)	10-20
Anode plate/foil	NaCl+Ni	no data
Electrolyte	NaAlCl4; β"-Al2O3 (beta-alumina solid electrolyte ((Na1.7Li0.3Al10.7O17)); BASE = ceramic electrolyte)	20-30
Separator	Polyolefin	5
Other	Small amounts of powdered iron, sodium fluoride (NaF), and iron or sulphide (dopants)	<1
Case and tab	Steel, plastic	20-30

Table 11: Battery components of sodium-nickel chloride-metal hydride batteries, their chemical compounds and the percentual share on the total battery mass[20]

Chemical compound	**Na-NiCl2**	**CAS No.**
NiCl2	Nickel dichloride	231-743-0
NaAlCl4	Sodium Tetrachloroaluminate	7784-16-9
β”-Al2O3	Beta-alumina solid electrolyte	not found
NaCl	Sodium chloride	7647-14-5
NaF	Sodium fluoride	7681-49-4
Ni3S2	Nickel sulphide	16812-54-7

[18] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[19] ZEBRA: Zeolite Battery Research Africa Project.
[20] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

Table 12: Chemical compounds of Na-NiCl2 batteries[21]

(iii) High temperature Sodium Sulphur (NaS)

78. A sodium-sulphur (NaS) battery system is an energy storage system based on electrochemical charge/discharge reactions that occur between a positive electrode (cathode) that is typically made of molten sulphur (S) and a negative electrode (anode) that is typically made of molten sodium (Na). The electrodes are separated by a solid ceramic, sodium beta alumina, which also serves as the electrolyte. This ceramic allows only positively charged sodium ions to pass through. The battery temperature is kept between 300° C and 360° C to keep the electrodes in a molten state, i.e. independent heaters are part of the battery system.

(d) Alkaline and Zinc batteries

(i) Alkaline batteries

79. Alkaline batteries derive energy from the reaction between a zinc metal (anode) and manganese dioxide (cathode; MnO2). Compared with zinc–carbon or zinc chloride batteries, that use acidic ammonium chloride (NH4Cl) or zinc chloride (ZnCl2) as electrolyte, the most commonly used electrolyte for an alkaline battery is potassium hydroxide (KOH). This alkaline electrolyte is also the namesake of the alkaline battery. Other components are graphite (carbon rod as collector), separator and binder, gasket and the casing (mainly steel; see the table, source: Safety Data Sheets from battery producers). [22]

80. The overall reaction in the alkaline battery is as follows:

$$Zn + 2\ MnO_2 \rightleftharpoons ZnO + Mn_2O_3$$

Battery component	**Chemical compound**	**Weight (% total battery)**
Cathode	MnO2	25-50
Anode	Zn (metallic)	10-25
Collector	Carbon rod	2-6
Electrolyte	KOH	5-15
Separator and binder	Cellulose in 50 % zinc- containing KOH	no data
Gasket	Polyolefin	no data
Case and tab	Steel	15-30

Table 13: Battery components of alkaline batteries, their chemical compounds and the percentual share on the total battery mass

Chemical compound		**CAS No.**
MnO2	Manganese dioxide	1313-13-9
Zn metallic	Zinc powder – zinc dust	7440-66-6
KOH	Potassium hydroxide	1310-58-3
Graphite	-	7782-42-5

Table 14: Overview on battery components of alkaline batteries[23]

(ii) Zinc batteries

81. Basically, Zinc batteries use zinc ions (Zn2+) as the charge carriers (anode). Zinc battery can be subdivided into zinc-carbon and zinc-chloride and zinc-air batteries. Silver zinc batteries are using as well Zn as anode, thereo these batteries are also considered in this section. Depending on the zinc battery type, different anodes and electrolytes are part of the battery cell. The following table provides the information of the battery components and chemical compounds of zinc-based batteries. [24]

82. The following list gives examples of the overall electrochemical reaction within the different type of zinc batteries:

[21] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[22] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[23] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[24] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

Zinc-carbon: $Zn + 2MnO_2 + 2NH_4Cl \rightarrow 2MnO(OH) + [Zn(NH_3)_2]Cl_2$

Zinc-chloride: $Zn + 2MnO_2 + H_2O \rightarrow Mn_2O_3 + Zn(OH)_2$

Zinc-air $Zn + O_2 \rightarrow 2ZnO$

Silver-zinc:

During the charging process, silver is first oxidized to silver(I) oxide ($2Ag(s) + 2OH^- \rightarrow Ag_2O + H_2O + 2e^-$) then to silver(II) oxide ($Ag_2O + 2OH^- \rightarrow 2AgO + H_2O + 2e^-$)

Zinc oxide is reduced to metallic zinc: $Zn(OH)_2 + 4e^- \rightleftharpoons 2Zn + 4OH^-$

Silver-oxide:

Overall reaction: $Zn + H_2O + Ag_2O \rightleftharpoons Zn(OH)_2 + 2Ag$

Overall reaction (anhydrous form): $Zn + Ag_2O \rightleftharpoons ZnO + 2Ag$

Figure 11: Electrochemistry of different Zinc batteries

Battery components	**Zinc-carbon**	**Zinc-chloride**	**Zinc-air**	**Silver zinc**	**Silver oxide**
	Zn-C	Zn-Cl	-	Ag-Zn	Ag-oxide
Cathode	MnO2	MnO2	O2	Ag(met)	Ag2O (Ag(I)O)
Anode	Zn	Zn	Zn	Zn and ZnO	Zn
Electrolyte	Mainly 20 % NH4Cl*, ZnCl (only part of the electrolyte)	only ZnCl	KOH	KOH	NaOH, KOH
Collector	Carbon rod	Carbon rod	-	-	-
Separator	-	-	membrane	membrane	membrane
Casing	Zn anode is at the same time battery can, steel on bottom and cap		Zn anode is at the same time battery can, Ag cathode is also part of the can		
Other	Carbon rod, cardboard		-	Plastic insulator (sealant), MnO2, graphite, can contain low concentration of mercury oxide	

Table 15: Battery components and compounds of zinc-based batteries [25]

83. Research in literature, mainly based on Safety Data Sheets from battery producers, revealed a great variability of certain components, even within the same battery chemistry. In the Safety Data Sheets for the silver containing batteries, the percentual distribution of the battery components was somehow similar for silver zinc and silver oxide. So no clear distinction between the two battery chemistries is presented in the table below.

Battery components	**Zinc-carbon**	**Zinc-chloride**	**Zinc-air**	**Silver zinc**	**Silver oxide**
	Weight (% total battery)				
Zn metallic	20-25 %	50-70 %	50-70 %	2-15 %	
MnO_2	40-50 %	10-20 %	-	0-3 %	
AgO	-	-	-	5-40 %	
NH_4Cl and ZnCl	10-20 %	15-30 %	-	-	
KOH	-	-	<10 %	0-10 %	
Carbon (rod)	5-6 %	5-15 %	-	0-5 %	
HgO	-	-	-	0-max. 1 %	
Other components (includes water, separator, binders, conductive agents)	10-15 %	-	<10 %	balance	
Steel	-	-	-	30-40 %	

Table 16: Percentual distribution of the zinc-based battery components (sources are Safety Data Sheets from battery producer) [26].

[25] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

[26] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

Chemical compound		CAS No.
	Zinc-carbon and Zinc-chloride	
MnO2	Manganese dioxide	1313-13-9
Zn metallic	Zinc powder – zinc dust	7440-66-6
NH4Cl	Ammonium chloride	12125-02-9
ZnCl	Zinc chloride	7646-85-7
	Zinc air	
Zn metallic	Zinc powder – zinc dust	7440-66-6
KOH	Potassium hydroxide	1310-58-3
	Silver Zinc	
Zn metallic	Zinc powder – zinc dust	7440-66-6
ZnO	Zinc oxide	1314-13-2
NaOH	Sodium hydroxide	1310-73-2
HgO	Mercuric oxide / Mercury(II) oxide	21908-53-2
	Silver oxide	
Zn metallic	Zinc powder – zinc dust	7440-66-6
Ag2O	Di-silver oxide (Ag(I)O)	20667-12-3
KOH	Potassium hydroxide	1310-58-3
NaOH	Sodium hydroxide	1310-73-2
HgO	Mercuric oxide / Mercury(II) oxide	21908-53-2

Table 17: Overview on different zinc-based batteries

(e) [Mixed batteries]

(f) Other type of batteries

II. Relevant provisions of the Basel Convention and international linkages

A. Basel Convention

1. General provisions

84. 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, as far as is compatible with environmentally sound and efficient management, be disposed of in the State where they are generated. A set of provisions of the Basel Convention lays out Parties obligations to ensure the ESM of wastes.

85. 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”. Management means the collection, transport and disposal of hazardous wastes or other wastes, including the aftercare of disposal sites. 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 related adverse effects.”

86. 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.”

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

88. 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."

89. [Under Article 4A (amendment adopted by Decision III/1, known as "Ban Amendment"), which entered into force on 5 December 2019, Parties listed in Annex VII to the Convention (members of the European Union (EU), Organization for Economic Cooperation and Development (OECD) and Liechtenstein) shall prohibit transboundary movements 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.[27] ["Other wastes" included in Annex II are not subject to the Ban Amendment.]]

2. Provisions relating to OWB:

90. According to article 1 ("Scope of the Convention"), the Basel Convention covers two types of waste subject to transboundary movement: "hazardous wastes" and "other wastes".

91. [Paragraph 1 of Article 1 sets out that hazardous wastes in the scope of the Basel Convention are:

(a) Wastes that belong to any category contained in Annex I, unless they do not possess any of the characteristics contained in Annex III; and

(b) Wastes that are not covered under paragraph (a) but are defined as, or are considered to be, hazardous waste by domestic legislation of the Party of export, import or transit.]

92. Constituents listed in Annex I in wastes batteries are e.g. zinc compounds Y23, cadmium Y26, , waste batteries are presumed to exhibit one or more Annex III hazardous characteristics, which may include H4.1"flammable solids"; H6.1 "Poisonous (Acute)";; H8 "Corrosives", H11 "Toxic (delayed or chronic)"; H12 "Ecotoxic"; or H13 (capable after disposal of yielding a material which possess a hazardous characteristic)[28], unless, through "national tests," they can be shown not to exhibit such characteristics. National tests may be useful for identifying a particular hazardous characteristic in Annex III of the Convention until such time as the hazardous characteristic is fully defined. Guidance

[27] 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 https://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx.

[28] See the Appendix for more details.

documents for Annex III hazardous characteristics H4.1, H11, H12 and H13 were adopted on an interim basis by the Conference of the Parties to the Basel Convention at its sixth and seventh meetings.

[

Annex I Categories of Wastes to be Controlled	
Zinc compounds	Y23
Cadmium	Y26
Basic solutions or bases in solid form	Y35
Annex II "Other wastes"	
Plastic waste, including mixtures of such waste, with the exception of the following: • Plastic waste that is hazardous waste pursuant to paragraph 1 (a) of Article 1[29] • Plastic waste listed below, provided it is destined for recycling[30] in an environmentally sound manner and almost free from contamination and other types of wastes:[31] - Plastic waste almost exclusively[32] consisting of one non-halogenated polymer, including but not limited to the following polymers: o Polyethylene (PE) o Polypropylene (PP) o Polystyrene (PS) o Acrylonitrile butadiene styrene (ABS) o Polyethylene terephthalate (PET) o Polycarbonates (PC) o Polyethers - Plastic waste almost exclusively[7] consisting of one cured resin or condensation product, including but not limited to the following resins: o Urea formaldehyde resins o Phenol formaldehyde resins o Melamine formaldehyde resins o Epoxy resins o Alkyd resins - Plastic waste almost exclusively[7] consisting of one of the following fluorinated polymers:[33] o Perfluoroethylene/propylene (FEP) o Perfluoroalkoxy alkanes: ▪ Tetrafluoroethylene/perfluoroalkyl vinyl ether (PFA) ▪ Tetrafluoroethylene/perfluoromethyl vinyl ether (MFA) o Polyvinylfluoride (PVF) o Polyvinylidenefluoride (PVDF) Mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided they are destined for separate recycling[34] of each material and in an environmentally sound manner and almost free from contamination and other types of wastes.[35]	Y48

[29] Note the related entry on list A A3210 in Annex VIII.

[30] Recycling/reclamation of organic substances that are not used as solvents (R3 in Annex IV, sect. B) or, if needed, temporary storage limited to one instance, provided that it is followed by operation R3 and evidenced by contractual or relevant official documentation.

[31] In relation to "almost free from contamination and other types of wastes", international and national specifications may offer a point of reference.

[32] In relation to "almost exclusively", international and national specifications may offer a point of reference.

[33] Post-consumer wastes are excluded.

[34] Recycling/reclamation of organic substances that are not used as solvents (R3 in Annex IV, sect. B), with prior sorting and, if needed, temporary storage limited to one instance, provided that it is followed by operation R3 and evidenced by contractual or relevant official documentation.

[35] The "Plastic waste amendments" adopted by decision BC-14/12: Amendments to Annexes II, VIII and IX to the Basel Convention" entered into force on 24 March 2020, except for those Parties that declared by then that they were unable to accept them by notifying the Depository in writing.

Electrical and electronic wastes (See para XXX below)	Y49
Annex III List of Hazardous Characteristics	
Flammable solids	H4.1
Poisonous (Acute)	H6.1
Corrosives	H8
Liberation of toxic gases in contact with air or water	H10
Toxic (delayed or chronic)	H11
Ecotoxic	H12
Capable after disposal of yielding a material which possess a hazardous characteristic unless they can be shown not to exhibit such characteristics	H13

Table 18 Annex I wastes to be controlled and Annex III hazardous characteristics]

93. At its fourth meeting in February 1998, the Conference of the Parties added the two lists of wastes as two new annexes to the Convention, namely Annex VIII (list A) and Annex IX (list B). These were intended to provide greater certainty and clarity to the entries. List A and List B are kept under review by the Conference of the Parties; in addition, a process was established under Decision BC VIII/15 of the Conference of the Parties to the Basel Convention to facilitate the identification and agreement on new entries. However, please note that Annex I and Annex III remain the factors to characterize wastes as hazardous for the purpose of this Convention, and that List A and List B are not intended to be exhaustive.

94. List A of Annex VIII describes wastes that are “characterized as hazardous under Article 1, paragraph 1 (a) of this Convention” although “their designation on this Annex does not preclude the use of Annex III [hazard characteristics] to demonstrate that a waste is not hazardous” (Annex I, paragraph (b)). List B of Annex IX lists wastes that “will not be wastes covered by Article 1, paragraph 1 (a), of this Convention unless they contain Annex I material to an extent causing them to exhibit an Annex III characteristic”.

95. As stated in Article 1, paragraph 2, “Wastes that belong to any category contained in Annex II that are subject to transboundary movement shall be “other wastes” for the purposes of this Convention”.

96. The Basel Convention contains entries on waste batteries other than WLAB in Annexe VIII of the Convention as follows:

A1170 Unsorted waste batteries excluding mixtures of list B batteries. Waste batteries not specified on list B containing Annex 1 constituents to the extent that render them hazardous.

A1181 Electrical and electronic waste[36] (note the related entry Y49 in Annex II)[37]:

Waste electrical and electronic equipment:

- containing or contaminated with cadmium, lead, mercury, organohalogen compounds or other Annex I constituents to an extent that the waste exhibits an Annex III characteristic, or
- with a component containing or contaminated with Annex I constituents to an extent that the component exhibits an Annex III characteristic, including but not limited to any of the following components:
    - glass from cathode-ray tubes included on list A
    - a battery included on list A
    - a switch, lamp, fluorescent tube or a display device backlight which contains mercury
    - a capacitor containing PCBs
    - a component containing asbestos

[36] This entry becomes effective on 1 January 2025.

[37] PCBs or PBBs are at a concentration level of 50 mg/kg or more in equipment, in a component, or in wastes arising from the processing of waste electrical and electronic equipment or waste components of electrical and electronic equipment.

- certain circuit boards
- certain display devices
- certain plastic components containing a brominated flame retardant

- Waste components of electrical and electronic equipment containing or contaminated with Annex I constituents to an extent that the waste components exhibit an Annex III characteristic, unless covered by another entry on list A.

- Wastes arising from the processing of waste electrical and electronic equipment or waste components of electrical and electronic equipment, and containing or contaminated with Annex I constituents to an extent that the waste exhibits an Annex III characteristic (e.g. fractions arising from shredding or dismantling), unless covered by another entry on list A.[38]

A4090 Waste acidic or basic solutions, other than those specified in the corresponding entry on list B (note the related entry on list B B2120)

97. The Basel Convention contains entries on waste batteries other than WLAB in Annexe IX of the Convention as follows:

B1090 waste batteries conforming to a specification, excluding those made with lead, cadmium or mercury.

98. The Basel Convention contains entries on waste batteries other than WLAB in Annex II of the Convention as follows:

- Y49 Electrical and electronic waste[39] .
  - Waste electrical and electronic equipment:
    i. not containing and not contaminated with Annex I constituents to an extent that the waste exhibits an Annex III characteristic, and
    ii. in which none of the components (e.g. certain circuit boards, certain display devices) contain or are contaminated with Annex I constituents to an extent that the component exhibits an Annex III characteristic.
  - Waste components of electrical and electronic equipment (e.g. certain circuit boards, certain display devices) not containing and not contaminated with Annex I constituents to an extent that the waste components exhibit an Annex III characteristic, unless covered by another entry in Annex II or by an entry in Annex IX.
  - Wastes arising from the processing of waste electrical and electronic equipment or waste components of electrical and electronic equipment (e.g. fractions arising from shredding or dismantling), and not containing and not contaminated with Annex I constituents to an extent that the waste exhibits an Annex III characteristic, unless covered by another entry in Annex II or by an entry in Annex IX.

B. International linkages

1. World Customs Organisation

99. 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 waste batteries other than WLAB, has been developed and maintained by the World Customs Organization (WCO).

100. Under the WCO Harmonized System[40] (HS) of tariff nomenclature sets the codes for moving traded products such as wastes as it specifically relates to transboundary movements. Waste batteries are classified and coded under Chapter 85 Electrical machinery, equipment and parts thereof.

101. The table from Trade Data Monitor below summarises codes that could be used for waste batteries other than WLAB:

[38] The amendments to annexes II, VIII and IX on electrical and electronic wastes (adopted by decision BC-15/18) became effective on 1 January 2025, except for those Parties that declared by then that they were unable to accept them by notifying the Depository in writing.

[39] See note 32.

[40] Harmonized System | WCO Trade Tools.

Code	Description
8506	primary cells and primary batteries; parts thereof
850610	primary cells and primary batteries, manganese dioxide
850630	primary cells and primary batteries, mercuric oxide
850640	primary cells and primary batteries, silver oxide
850650	primary cells and primary batteries, lithium
850660	primary cells and primary batteries, air-zinc
850680	primary cells and primary batteries, n.e.s.o.i.
850690	parts of primary cells and primary batteries
8507	electric storage batteries, including separators therefor; parts thereof
850710	*lead-acid storage batteries of a kind used for starting piston engines*
850720	*lead-acid storage batteries n.e.s.o.i.*
850730	nickel-cadmium storage batteries
850740	nickel-iron storage batteries
850750	nickel-metal hydride batteries
850760	lithium ion batteries
850780	storage batteries n.e.s.o.i.
850790	parts of electric storage batteries, including separators therefor
8513	portable electric lamps designed to function on own energy source (dry batteries, storage batteries, magnetos), except for motor vehicles etc.; parts
8548	waste & scrap of primary cells and batteries; spent primary cells and batteries; electrical parts of machinery or apparatus, nesoi
854810	waste and scrap of primary cells, primary batteries and electric storage batteries; spent primary cells, spent primary and electric storage batteries
854910	waste and scrap of primary cells, primary batteries and electric accumulators; spent primary cells, spent primary batteries and spent electric accumulators
854912	primary cells, primary batteries and electric accumulators (excl. lead-acid): spent goods and waste and scrap, containing lead, cadmium or mercury
854913	primary cells, primary batteries and electric accumulators: spent goods and waste and scrap, sorted by chemical type, not containing lead, cadmium or mercury
854914	primary cells, primary batteries and electric accumulators: spent goods and waste and scrap, unsorted, not containing lead, cadmium or mercury
854919	primary cells, primary batteries and electric accumulators: spent goods and waste and scrap, sorted but not by chemical type, not containing lead, cadmium or mercury
854921	electrical and electronic waste and scrap, of a kind used principally for the recovery of precious metal, containing primary cells, primary batteries, electric accumulators, mercury-switches, glass from cathode-ray tubes or other activated glass, or electrical or electronic components containing cadmium, mercury, lead or polychlorinated biphenyls "pcbs"
854929	electrical and electronic waste and scrap, of a kind used principally for the recovery of precious metal (excl. containing primary cells, primary batteries, electric accumulators, mercury-switches, glass from cathode-ray tubes or other activated glass, or electrical or electronic components containing cadmium, mercury, lead or polychlorinated biphenyls "pcbs")
854931	waste and scrap of electrical and electronic assemblies and printed circuit boards, containing primary cells, primary batteries, electric accumulators, mercury-switches, glass from cathode-ray tubes or other activated glass, or electrical or electronic components containing cadmium, mercury, lead or polychlorinated biphenyls "pcbs" (excl. for the recovery of precious metal)
854939	waste and scrap of electrical and electronic assemblies and printed circuit boards (excl. for the recovery of precious metal, or containing primary cells, primary batteries, electric accumulators, mercury-switches, glass from cathode-ray tubes or other activated glass, or electrical or electronic components containing cadmium, mercury, lead or polychlorinated biphenyls "pcbs"
854991	electrical and electronic waste and scrap, containing primary cells, primary batteries or electric accumulators but not predominantly, or containing mercury-switches, glass from cathode-ray tubes or other activated glass, or electrical or electronic components containing cadmium, mercury, lead or polychlorinated biphenyls "pcbs" (excl. for the recovery of precious metal, and electrical and electronic assemblies and printed circuit boards)
854999	electrical and electronic waste and scrap (excl. for the recovery of precious metal, electrical and electronic assemblies and printed circuit boards, and containing primary cells, primary batteries,

Code	Description
	electric accumulators, mercury-switches, glass from cathode-ray tubes or other activated glass, or electrical or electronic components containing cadmium, mercury, lead or polychlorinated biphenyls "pcbs")
8601	rail locomotives powered from an external source of electricity or by electric accumulators (batteries)
860120	rail locomotives powered by electric accumulators (batteries)

Table 19: HS Codes for OWB

2. Heavy Metals Protocol

102. 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 mercury and cadmium, 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. The Global Framework on Chemicals

103. In September 2023, the fifth session of the International Conference on Chemicals Management adopted a Global Framework on Chemicals. The framework is based around 28 targets that aim to improve the sound management of chemicals and waste. Governments have committed to creating, by 2030, the regulatory environment to reduce chemical pollution and implement policies to promote safer alternatives. Industry has committed to managing chemicals in a way that reduces chemical pollution and adverse impacts by 2030. In accordance with the framework, stakeholders can submit issues of concern, which will be considered and prioritized by the International Conference on Chemicals Management, at its meetings.

4. [Organisation for Economic Co-operation and Development

104. 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). The OECD Council Decision (2022)[41] on the transboundary movement of waste for recovery aims at facilitating the trade of recyclables in an environmentally sound and economically efficient manner by using a simplified procedure as well as a risk-based approach to assess the necessary level of control for materials. Wastes exported outside the OECD area, whether for recovery or final disposal, do not benefit from this simplified control procedure.

105. Further information may be found in the guidance manual for the implementation of the OECD recommendation on ESM of waste (OECD, 2007)[42].]

5. International Labour Organisation (ILO)

(a) ILO Chemical Conventions & Recommendation, 1990

106. 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[43].

107. 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

[41] https://www.oecd.org/env/waste/theoecdcontrolsystemforwasterecovery.htm.

[42] 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.

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

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.

108. 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.

109. The list of classified chemicals includes heavy metals, 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 waste batteries.

(b) ILO Code of Practice – safety & health

110. 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. The code aims to ensure that the safety and health of all those involved in 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.

111. 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[44].

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

113. 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.

6. World Health Organization (WHO)

114. The WHO has published fact sheets on chemical safety and health for various substances including mercury, cadmium and nickel. These publications explain how these substances can cause significant environmental contamination and human exposure. It provides information about the main routes of exposure, the health impacts, the associated burden of its effects, methods for assessing exposure, and the types of control measures needed to prevent emissions and exposures.

115. WHO aims to inform the health sector on the issues around various metals, such as mercury, cadmium and nickel and human health so that they recognize that the recycling and handling of products containing these substances are a source of exposure and can assist in ensuring that effective controls are in place. In addition it aims to inform policy makers of the health issues surrounding metals exposure to stimulate the introduction and enforcement of controls.

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

7. Stockholm Convention on Persistent Organic Pollutants (POPs)

116. The Stockholm Convention on Persistent Organic Pollutants[45] was adopted in May 2001 and came into force in May 2004. The objective of the convention is to protect human health and the environment from POPs. The Convention requires each Party to prohibit and/or take the legal and administrative measures to eliminate the production and use of chemicals listed in Annex A. The Convention also requires the parties to restrict/eliminate the production and use of the chemicals listed in Annex B.

117. Article 5 requires each party as a minimum to take measures to reduce or eliminate releases from unintentional anthropogenic sources of the chemicals listed in Annex C for example PCDD/PCDF hexachlorobenzene (HCB), hexachlorobutadiene (HCBD), pentachlorobenzene (PeCB), polychlorinated biphenyls (PCBs), and polychlorinated naphthalenes (PCNs).

118. Under Annex C – Unintentional Production – Part II lists industrial sources which have the potential for comparatively high formation and releases of these chemicals into the environment. In Part III there are a list of other source categories that unintentionally produce POPs, and these include among others thermal processes in the metallurgical industry, which will include secondary lead smelting as this is not mentioned in Part II.

119. Annex C Part V provides general prevention measures relating to both best available techniques and best environmental practices to reduce or eliminate the releases of chemicals listed in Part I (e.g. PCDD/PCDF) for both new and existing facilities.

III. Guidance on the environmentally sound management (ESM) of Other Waste Batteries

A. General considerations

120. Environmentally sound management (ESM)[46] 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.[47,48.]

1. Basel Convention

121. 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.]

122. As presented in the section II (Relevant provisions of the Basel Convention and international linkages) 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

[45] https://chm.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx.

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

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

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

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[49] and the circular economy. This approach can make a significant contribution to resource recovery, reduce energy inputs and assist tackling global warming. 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 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 Other Waste Batteries

123. 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 batteries, performance should be assessed during the following stages: production of batteries, their uses; collection and transportation of waste batteries; and their recycling and reuse of the recovered wastes and the final disposal of the waste that cannot be recovered.]

B. Legislative and regulatory framework

124. 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 OWB.

125. 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 batteries, including provisions for inspections and for establishing penalties for violations (e.g., on illegal shipments).

126. The legislation should enable relevant authorities to monitor whether facilities where wastes batteries are stored, collected, transported, and disposed of, 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 minimum requirements that those involved in waste battery management (e.g., generators, collectors, transporters, and recyclers) ensure that the collection, transportation, storage and disposal facilities operate in an environmentally sound manner.

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

127. 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[50]. The legislative and regulatory approach to adopting a sound ESM for waste batteries should include for example:

(a) Registration of waste generators;

(b) Registration of waste carriers;

(c) Authorization of waste storage facilities;

(d) Authorization of waste disposal facilities.

1. Extended producer responsibility

128. 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"[51]. "Producer"[52] 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 collection, sorting, 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.

129. 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 raise public awareness of the correct routes for collection sorting, treatment and disposal and (5) to promote innovation in recycling technology. EPR therefore promotes a market in which prices reflect the environmental costs of products (OECD 2001a).[53] Detailed descriptions of EPR schemes are available in several OECD publications on the issue[54].

130. 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 batteries collected and recycled, 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 the cost related to their product.. For example, in the EU Member States there are already EPR systems for portable and industrial batteries based on the requirements of the Battery Directive 2006/66EC and the new Regulation (EU) Batteries Regulation (EU) 2023/1542 replacing the Directive is extending EPR schemes to all battery categories (portable, LMT, SLI, EV and industrial) and deepening them by including specific waste collection targets, as well as specific recycling efficiency targets and material recovery targets.

131. [Each party, when developing and implementing extended producer responsibility, is guided by its own national conditions and the experience of countries where extended producer responsibility has been implemented and is being implemented].

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

[51] UNEP/CHW.14/5/Add.1
https://www.basel.int/Implementation/CountryLedInitiative/EnvironmentallySoundManagement/ESMToolkit/Practicalmanuals/tabid/5847/Default.aspx.

[52] 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.

[53] https://www.oecd.org/environment/extended-producer-responsibility.htm.

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

132. Further guidance on EPR is available in the practical manual on extended producer responsibility adopted by decision BC-14/3, in "Extended Producer Responsibility - Guidance for efficient waste management" (OECD, 2016) and in "Development of Guidance on Extended Producer Responsibility (EPR)" (European Commission, 2014).

2. Reduction and phase-out of cadmium related to OWB

3. Transboundary movement requirements

133. 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. As far as is compatible with their ESM, wastes should be disposed of in the country where the waste was generated (i.e. proximity principle) [55]. Under the environmentally sound management of wastes, shipments should go to locations which meet the requirements set out in the technical guidance.

134. Although transboundary movements of wastes are permitted, except when regulated by the Ban Amendment, in the Parties which have ratified it or when national prohibitions of import or export of hazardous and other wastes were communicated to the Secretariat, (Article 4 paragraph 1 of the Basel Convention).

135. Parties shall take the appropriate measures to ensure that the transboundary movement of hazardous waste and other wastes only be allowed if:

(a) the state 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 manner; or

(b) if the wastes in question are required as a raw material for recycling or disposal in the State of import; or

(c) the transboundary movement in question is in accordance with other criteria established by the Parties provided any criteria do not depart from the objectives of the Convention;

(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 Annex IVA and hazardous wastes under Article 1.1(a) which are destined to operations according to Annex IVB[56];

(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[57];

(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, in a timely manner, 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);

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

[56] http://www.basel.int/Countries/StatusofRatifications/BanAmendment/tabid/1344/Default.aspx.

[57] https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23.

(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.

4. Specifications for containers and storage sites

136. Packaging used to transport wastes must be made of materials that do not react with wastes and be constructed so as to remain closed under normal transport conditions; most of the batteries are classified as dangerous goods for the transport, when they became waste these batteries must be transported with packaging provided by these regulations, in safer condition.

137. The transport of dangerous goods is regulated to prevent, as far as possible, accidents to people or things and damage to the environment, to the means of transport used or to other goods, storing the batteries in their containers guarantees a higher level of protection.

138. Most of waste batteries are dangerous goods, only alkaline batteries and nickel-zinc batteries are not subject to the rules of transport of dangerous goods and they don't need an approved packaging.

139. The storage in container of waste batteries at intermediate multimodal sites or at final destination does not represent a problem if they have been packaged correctly by the consignor, however, it is necessary to take precautions in the case of the presence of lithium batteries:

(a) The chosen place must be suitable for keeping thermal variations to a minimum;

(b) Direct sunlight should be avoided as much as possible;

(c) A temperature detection system is also helpful;

(d) Containers equipped with emergency systems capable of intervening automatically in the event of fire is recommended.

140. The storage in packages can be indoors or outdoors, in both cases it is necessary to avoid:

(a) the possibility of flooding both by watercourses and by accumulation of rainwater;

(b) proximity to other sources of danger, such as high voltage cables, transformer cabins, flammable or corrosive gas or liquid tanks, or other storage areas for potentially dangerous material;

(c) direct sunlight should be avoided as much as possible.

141. The storage usually takes place in racks, otherwise a maximum of two pallets are allowed on top of each other, provided that this is permitted within the usage instructions of the packaging.

142. The batteries must be kept protected from atmospheric agents in such a way as to facilitate the reduction of the humidity rate near the batteries, the position with respect to circulation within the plant, escape routes, ease of movement in the event of an accident to facilitate the intervention of firefighters.

143. The primary danger associated with the storage of lithium-containing energy carriers is the possibility of a so-called thermal runaway. There are no regulations on the storage of these batteries, only good practice recommendations, in particular published in Italy [58] and the Netherland[59].

144. A thermal runaway is an uncontrolled increase in temperature, resulting from greater heat production than heat dissipation. In a thermal runaway, the temperature increase is the result of a positive feedback mechanism. An increase in temperature leads to an increase in the reaction rate and therefore (in the case of an exothermic reaction) to an increase in heat production. If this extra heat cannot be removed or cannot be removed quickly enough, the temperature of the reaction mixture rises, which further increases the reaction rate and heat production.

145. A thermal runaway reaction can lead to a very rapid increase in pressure and temperature and therefore an explosion or fire of the energy carrier, releasing (highly) flammable and toxic reaction products. Substances that may be released include solvents, hydrogen, carbon monoxide and HF (hydrogen fluoride). This poses a risk of (delayed) fire/explosion and serious health effects.

146. The quantity of batteries or the maximum energy stored in a single storage element (e.g. a pallet, a shelf, an automatic warehouse compartment) must be kept to the minimum compatible with

[58] Rischi connessi con lo stoccaggio di sistemi di accumulo Litio-ione (Vigili del Fuoco, ENEA, 2021).

[59] 37[2] Lithiumhoudende energiedragers: Opslag - Richtlijn voor de veilige opslag van lithiumhoudende energiedragers (December 2023).

the structure of the warehouse and the required materials workflow. Increasing this energy increases the level of danger.

147. The construction materials of the structures must be such as to minimize the risk of structural failure caused by temperature with consequent variation in the position of the elements in the warehouse, considering that during thermal runaway temperatures of 900 °C can be reached.

148. Packages must be stored in such a way that heat propagation is prevented, by distance or by thermally insulating and totally fireproof material; waste batteries and also stable damaged and defective batteries, must be stored in a fire compartment with a REI of at least 90 minutes.

149. This fire compartment must be directly accessible from outside to the fire brigade and the doors must be closed when not in use for transport, for example.

150. If storage in another fire compartment is not possible, storage must take place in a separate storage compartment, which is provided with a minimum fire-resistant separation of at least 90 minutes in the side and rear directions relative to the front of the rack section.

151. The front of the rack section may cover an open side with a free space of at least 5 m. If the front of the rack section is equipped with a fire-resistant partition such as a cloth, door or other access structures, this distance can be reduced to 2.5 m.

152. If storage is not possible in a separate storage compartment, the energy carriers are stored in packaging that complies with ADR packaging instruction P908 or LP904, whereby a maximum of 5 filled packages may be present in the relevant fire compartment.

153. The 90 min REI required can also be achieved:

(a) when the distance from the storage facility to the boundary of the location, another structure belonging to the location or other flammable objects is less than 5 m, the fire resistance of the walls, roof and supporting structure of the storage facility must be at least 90 minutes. Doors, ventilation openings, pipe penetrations or smoke hatches in this construction may not detract from the required fire resistance;

(b) when the distance from the storage facility to the boundary of the location, another structure belonging to the location or other flammable objects is at least 5 meters, the fire resistance of the walls, roof and supporting structure of the storage facility must be at least 60 minutes . Doors, ventilation openings, pipe penetrations or smoke hatches in this construction may not detract from the required fire resistance;

(c) when the distance from the storage facility to the boundary of the location, another structure belonging to the location or other flammable objects is at least 10 meters, the fire resistance of the walls, roof and supporting structure of the storage facility must be at least 30 minutes amounts. Doors, ventilation openings, pipe penetrations or smoke hatches in this construction may not detract from the required fire resistance;

(d) if the distance from the storage facility to the boundary of the location, another structure belonging to the location or other flammable objects is at least 15 meters, no additional requirements are imposed for the fire resistance of the walls, roof and supporting structure.

5. Requirements for treatment facilities for OWB

154. The term "treatment" identifies any operation carried out on waste batteries after they have been handed over to a facility for sorting, preparation for recycling or for recycling.

155. Any facility carrying out treatment of batteries should comply with minimum requirements to prevent adverse impacts on the environment and human health and to allow a high degree of recovery of materials present in batteries.

156. Below we report what is foreseen by the EU's new Batteries Regulation 2023/1542, Annex XII Part A:

(a) Treatment shall, as a minimum, include removal of all fluids and acids.

(b) Treatment and any storage, including temporary storage, at treatment facilities, including recycling facilities, shall take place in sites with impermeable surfaces and suitable weatherproof covering or in suitable containers.

(c) Waste batteries in treatment facilities, including recycling facilities, shall be stored in such a way that they are not mixed with waste from conductive or combustible materials.

(d) Special precautions and safety measures shall be in place for the treatment of waste lithium-based batteries during handling, sorting and storage. Such measures shall include protection from exposure to:

(i) excessive heat, such as high temperatures, fire or direct sunlight;

(ii) water, such as precipitation and flooding;

(iii) any crushing or physical damage.

Waste lithium-based batteries shall be stored in their normally installed orientation, that is, never inverted, and in well-ventilated areas and they shall be covered with a high voltage rubber isolation. Storage facilities for waste lithium-based batteries shall be marked with a warning sign.

(e) Mercury shall be separated during treatment into an identifiable stream, which is safely immobilised and disposed of and cannot cause adverse effects on human health or the environment.

(f) Cadmium shall be separated during treatment into an identifiable stream, which is given a safe destination and cannot cause adverse effects on human health or the environment.

6. Other legislative controls

157. Examples of other aspects of the management of waste batteries that can be regulated through legislation, a permitting/approval process which includes management instrument and include:

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

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

(c) Decommissioning requirements for waste batteries 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;

(iv) Establishment of the need for financial guarantee for remediation works.

(d) 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 [60], including requirements for annual reporting and regular third-party auditing and verification after an incident;

158. Restrictions on greenhouse gas (GHG) emissions across the life cycle of OWB including their management as wastes, including such restrictions as are required to meet nationally determined contributions for parties to the Paris Agreement and encourage greater waste batteries recycling and resource conservation.

C. Waste prevention and minimization

1. General considerations

159. 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.

160. 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

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

preferred option in any waste management policy, so that the need for waste management is reduced, enabling resources to be used more efficiently.

161. 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".

162. 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).

163. The ESM framework states that those 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).

164. A practical manual on waste prevention, as part of the set of practical manuals for the promotion of the ESM 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.

D. Identification and inventory

1. Identification of sources of OWB [other waste batteries]

165. 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. A practical guidance for the development of ~~an~~ inventories of waste batteries containing lithium was developed under the Basel Convention[61].

2. Inventories

166. Inventories are an important tool for identifying, quantifying, and characterizing arisings. When developing an inventory priority should be given to the identification of the potential significant stakeholders in the value chain and life cycle for the batteries being considered, including in the waste stage prioritizing the identification of the potential significant producers and recyclers, high volume wastes managers and areas of greatest concern (e.g. locations with significant environmental and health risk, existence of informal collection, disposal or recycling sector, household collection sites etc.) and disposers.

167. National inventories may be used:

(a) To establish a baseline quantity of battery manufacturers, importers, exporters, retailers, distributors, batteries producers, collectors, transporters, exporters and 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 [other waste batteries].

168. 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

[61] https://www.basel.int/Countries/NationalReporting/Guidanceoninventoryofhazardouswastes/tabid/8755/Default.aspx.

reporting obligations under the Basel Convention. In addition, Parties may consult the toolkit for the development of an inventory of batteries containing Lithium[62].

3. Developing a national management plan for the ESM of waste batteries other than WLAB

169. The development of a national management plan for the ESM of waste batteries other than WLAB should be based on a review of the existing situation, especially where there are limited controls and regulations limited information on their management and rural remote communities. [Information from the data obtained in identifying the sources of waste batteries and inventories will greatly assist this process. The review, with defined deadlines and responsibilities 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 batteries are disposed (formally and informally) 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, including in-field data collection of the informal sector;

(e) **Raise public awareness:** the public should be made aware of the health and environmental issues associated with improper and non-environmentally sound recycling and disposal. 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 waste batteries 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 waste batteries other than 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 recycling is not illegally carried out in remote areas;

(i) **Monitoring:** for monitoring and supervision of the ESM of waste batteries other than WLAB management through the life cycle, 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. Sampling, analysis and monitoring

170. Sampling, analysis and monitoring all [batteries and waste batteries] components of lead such as lead, plastics, acid, wastes 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

Commented [FC3]: SA make the same changes in the parallel paragraph in the WLAB TGs

Commented [FC4]: To be adapted to the components of OWBs

[62] https://www.basel.int/Countries/NationalReporting/Toolkitsforwasteinventory/tabid/9043/Default.aspx.

subjected to rigorous quality 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.

171. 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.

172. For information on good laboratory practices, the OECD series on best of laboratory practice[63] may be consulted.

1. Sampling

173. 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 (e.g. hazardous or non-hazardous) 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.

174. 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, background or control samples 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 battery wastes are generated and time and date of sample-taking (including description and geographic coordinates);

(c) Type of analysis to be performed, 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.

175. 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 hazardous substances 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.

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

177. Hazardous substances can occur and be sampled in liquids, solids, gases and biota:

(a) Liquids:

(i) Leachate from landfills/dump sites;

(ii) Liquid collected from spills;

[63] https://www.oecd-ilibrary.org/environment/oecd-series-on-principles-of-good-laboratory-practice-and-compliance-monitoring_2077785x.

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

(b) Solids:

(i) Stockpiles of waste batteries other than WLAB;

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

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

(c) Gases:

(i) Air emissions of facilities handling waste batteries other than WLAB;

(ii) Metal 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.

178. 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

179. Analysis relates to the extraction, purification, separation, identification, quantification and reporting of hazardous substances 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 the chemical components (e.g., successful participation in inter-laboratory comparison studies and in external proficiency testing schemes).

180. 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 and calibration of analytical equipment;

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

(d) Training of laboratory staff.

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

3. Monitoring

182. 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”.

183. Monitoring programmes should be implemented for facilities managing/handling/recycling waste batteries, 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 waste batteries are properly managed, to identify potential issues relating to possible hazardous substances releases or exposure to these substances to determine whether amendments to the management approach might be appropriate.

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

1. General Considerations

184. The procedures for the handling, separation, collection, packaging, labelling, transportation and storage of OWB pending their disposal are generally similar to those applicable for hazardous wastes. **T**he Basel Convention Annex IV includes some operations related to the separation, re packaging and storage (D14 & D15) if any waste battery is intended to be disposed of by an operation listed in Section A, and R12 & R13 if they are intended to be disposed of by an operation listed in Section B. In the case of an R12/13 or D13-15 operation, PIC notification form requires information on any subsequent R1-11 or D1-12 facilities when required.

185. Specific guidance on the most appropriate handling of waste 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[64]. For transport and the transboundary movement of OWB that are classified as hazardous wastes, the following documents should be consulted to determine specific requirements.

2. Handling

186. Those who handle waste batteries other than WLAB should, taking into consideration relevant national regulations, pay special attention to the prevention of chemical releases into the environment and health and safety requirements. ESM requires particular precautions for the handling, separation, collection packaging and storage.

187. End users should safely handle and prevent any breakage of or damage. Wastes of products containing heavy metals should be handled safely and should not be discharged onto the unprotected ground or into storm sewers or other rainfall runoff collection systems. If waste batteries are accidentally broken or spilled, clean-up procedures should be followed.

Commented [FC5]: Norway: refer to the risk of fires in handling Lithium-ion batteries

Commented [FC6]: China, to check that end users and or waste managers and the text included in WLAB TGs can be consistently reflected in the TGs on OWBs

188. To ensure that releases of hazardous substances from batteries other than WLAB are kept to a minimum, it is important to first raise awareness and educate those involved in handling, separation, collection, packaging, labelling, transportation and storage (e.g., salvagers, transporters, recyclers, and treatment operators) about any chemicals. Such awareness raising can be achieved through training, labelling and data information sheets.

3. Separation

189. Separate collection of waste batteries is important because if such wastes are simply disposed of, e.g., as part of municipal solid waste (MSW), without any separation, the heavy metals and other hazardous substances could be released into the environment. To increase separate collection batteries should be labelled with different symbols and or colours to identify their chemistry or category. In addition, collection and take-back points for different waste streams such as waste batteries can be labelled with (uniform) logos/labelling.

190. OWB should be collected separately and not be disposed of in the general waste stream. This is best facilitated through the labelling of batteries showing they contain substances such as mercury, nickel and cadmium, for example, and that they should be recycled, as appropriate, 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 separate collection and 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 hazardous substances 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.

191. Manufacturers should indicate the presence of hazardous substances in products containing by using the international chemical symbols on product labels. 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.

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

4. Collection

192. To successfully achieve ESM of OWB there is a need for the installation of an appropriate collection and recovery infrastructure. When recycling facilities are not present in a country, sorting and a separate collection is recommended to avoid incorrect disposal with other waste streams, for example, those non-hazardous or organic household wastes. 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 valuable materials and the number of batteries circulating there are financial incentives to recover them.

193. There are several established ways of collecting OWB, these include:

(a) National collection schemes;

(b) Municipal waste ~~disposal facilities~~[collection systems or schemes and collection points;]

(c) Local collection schemes.

194. Some countries have the dual system of distribution-collection 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 disposal 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.

195. [Those collecting batteries should only transfer/sell them on to a licensed facility that is authorised to recycle waste batteries in an environmentally sound operation. Informal recycling operations are a key source of pollution with the potential to cause significant human health issues and environmental damage. It is therefore important that collectors only transfer waste batteries 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.]

196. Collectors or dealers should not break the batteries into separate components and ship or transport those components. 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

197. These schemes involve collecting waste batteries 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 centres or licensed recycling plants. 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.

(b) Municipal Waste Collection Systems

198. Many industrialised countries provide temporary storage facilities, often free of charge, for members of the local community to bring their waste to them (e.g. car batteries, golf cart batteries, leisure batteries) that 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 waste batteries that may otherwise be difficult to enter the recycling system. In addition, small businesses can also use these facilities, but they may incur a small charge. Often these facilities store batteries for recycling and have designated containers for different types of batteries. The facility may have a contract with a battery collection company to provide plastic bins, which they come and collect, for storing the batteries.

(c) Local Collection Systems

199. Whilst a common method of collecting waste batteries is through the battery retailers taking them back, remote users may find it difficult to use a collection scheme. The battery retailer may be some distance away in remote areas, which reduces the likelihood that the consumer will want to return the waste battery.

200. In low and middle-income countries, individual salvagers/recyclers will collect discarded materials that can be reused or recycled or sold. They will call at premises for waste batteries so that they might collect it with the prospect of a payment from a trader or recycler. These salvagers are very

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Norway add reference to commercial collection points
Canada: add other collection schemes as d)
See the collection in the mercury guidelines
Maurit. , among others after include

Commented [FC9]: China to check and update the language efficient at finding and collecting waste batteries, especially in remote locations. The key issue here will be to ensure human health and the environment are properly safeguarded for those collecting and salvaging waste batteries.

5. Packaging and labelling

201. Waste batteries 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 GHS - United Nations Globally Harmonized System of Classification and Labelling of Chemicals and UN Model Regulation - Recommendations on the Transport of Dangerous Goods should be consulted. International standards for the proper packaging, labelling and identification of wastes have been developed, including the following reference materials:

(a) UNECE, 2023, *Recommendations on the Transport of Dangerous Goods – UN Model Regulations*[65]*;*

(b) UNECE, 2023. *Globally Harmonized System of Classification and Labelling of Chemicals*[66] .

202. Given the different types of waste batteries they should be sized and sorted by type. [For all wastes, the rule applies that it is contained in packaging made of materials that do not react in contact with the waste and are weakened by it and furthermore that it is closed and remains closed during transport. However, if the waste is also classified as dangerous for transportation, then only the packaging required by the UN Model Regulation and the specific transport methods (road, sea, air) must be used].

203. If they are [authorized to be] 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. [The personnel involved in the preparation of the dangerous goods to transport must be trained. In the next paragraph the different transport conditions are illustrated.]

204. UN 2794 approved leakproof plastic 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.

6. Transportation

205. Waste batteries classified as a hazardous waste needs to be handled appropriately when being transported. Waste must be transported in suitable packaging; if it is dangerous goods then only the packaging required by the UN Model Regulation must be used as modified by the specific transport methods you intend to use: land, sea, air. While for maritime and air transport international regulations apply, respectively IMDG Code[67] and ICAO-TI[68]/IATA DGR[69], for land transport (road, rail, inland waterways) reference must be made to the geographical areas affected by the journey, so for example, we will use the ADR/RID/ADN regulation in the European continent, the DOT in the USA, the TDG Regulation in Canada and so on.

206. The basis of all regulations for the transport of dangerous goods, including waste, is the UN Model Regulation, published by UNECE (Geneva) and periodically updated by the Sub-Committee of Expert on Transportation of Dangerous Goods (SCETDG), dangerous goods are authorized to be transported only under the conditions established by this regulation. For wastes we must make an important premise: there is no correlation between hazardous waste codes and dangerous goods UN number:

207. [Hazardous Waste differ from Dangerous Good.]

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[65] https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23.
[66] https://unece.org/transport/dangerous-goods/ghs-rev10-2023.
[67] https://www.imo.org/en/OurWork/Safety/Pages/DangerousGoods-default.aspx.
[68] https://www.icao.int/safety/DangerousGoods/Pages/Doc9284-Technical-Instructions.aspx.
[69] https://www.iata.org/en/publications/dgr/.

208. Not all batteries and their wastes are dangerous goods for transport. The safe transport conditions of batteries may change depending on their dangerous characteristics, therefore there will be multiple conditions depending on the type of battery, furthermore in the case of lithium batteries they change if they are damaged or defective; it is possible to check the transport conditions of batteries classified as dangerous at the following free access site: www.batteriestransport.org

Battery type	UN No. - Proper shipping name Special provision - Packing Instruction	Class Hazard Label
	a) Lithium based batteries	
• Lithium metal (including lithium alloy batteries)	UN 3090 LITHIUM METAL BATTERIES UN 3091 "UN 3091 LITHIUM METAL BATTERIES PACKED WITH EQUIPMENT" UN 3091"UN 3091 LITHIUM METAL BATTERIES CONTAINED IN EQUIPMENT" SP 377 - P909	9 MISCELLANEOUS DANGEROUS SUBSTANCES AND ARTICLES, 
• Lithium ion • Lithium Solid State (including lithium ion polymer batteries)	UN 3480 LITHIUM ION BATTERIES UN 3481 UN 3481 LITHIUM ION BATTERIES PACKED WITH EQUIPMENT UN 3481 UN 3481 LITHIUM ION BATTERIES CONTAINED IN EQUIPMENT SP 377 - P909	9 MISCELLANEOUS DANGEROUS SUBSTANCES AND ARTICLES, 
	b) Nickel based batteries	
• Nickel-Iron (NiFe)	UN 2795 BATTERIES, WET, FILLED WITH ALKALI, electric storage SP 117 - P801	8 CORROSIVE SUBSTANCES 
• Nickel Zinc (NiZn)	Dry small batteries - Not regulated	-
• Nickel Cadmium (NiCd)	UN 2795 BATTERIES, WET, FILLED WITH ALKALI, electric storage UN 2800 BATTERIES, WET, NON-SPILLABLE, electric storage SP 117 - P801	8 CORROSIVE SUBSTANCES 
• Nickel Metal Hydride (NiMH)	UN 3496 BATTERIES, NICKEL-METAL HYDRIDE Note: Regulated only in Maritime transport SP 117	9 MISCELLANEOUS DANGEROUS SUBSTANCES AND ARTICLES, 
	c) Sodium based batteries	
• Sodium ion	UN 3551 SODIUM ION BATTERIES with organic electrolyte BATTERIES, CONTAINING METALLIC SODIUM OR SODIUM ALLOY UN 3552 SODIUM ION BATTERIES CONTAINED IN EQUIPMENT, with organic electrolyte	9 MISCELLANEOUS DANGEROUS SUBSTANCES AND ARTICLES, 

Battery type	UN No. - Proper shipping name Special provision - Packing Instruction	Class Hazard Label
	UN 3552 SODIUM ION BATTERIES PACKED WITH EQUIPMENT, with organic electrolyte SP 377 - P909	
• High Temperature Sodium Nickel Chloride (NaNiCl) • High temperature Sodium Sulphur (NaS)	UN 3292 BATTERIES, CONTAINING SODIUM From 1.1.2025: UN 3292 BATTERIES, CONTAINING METALLIC SODIUM OR SODIUM ALLOY SP 239 - P601	4.3 SUBSTANCES WHICH IN CONTACT WITH WATER EMIT FLAMMABLE GASES 
d) Alkaline and Zinc batteries		
	Small dry batteries - Not regulated	-
e) [Mixed batteries]		
	If the mix portable batteries contain Lithium batteries, they must be transported as UN 3480 or 3090 SP377 - P909	If contain LiB → 9 MISCELLANEOUS DANGEROUS SUBSTANCES AND ARTICLES 
f) Other types of batteries		
• Reserve batteries (activated by filling them with water)	UN 3028 BATTERIES, DRY, CONTAINING POTASSIUM HYDROXIDE SOLID, electric storage SP 304 - P801	8 CORROSIVE SUBSTANCES 

Table 20: Classification of dangerous batteries for transport purposes:

209. During transport, batteries of different types have several risks in common which must be reduced by adopting appropriate procedures:

(a) protect them from short circuits- minimizes movement with cautioning material to avoid the risk of damage and electrolyte leakage;

(b) follow the special provision and the packing instruction provided for each battery;

(c) packaging should be secured on pallets to prevent movement with straps on the truck floor, side panels or side bars will assist retaining the load.

210. There is also the possibility to transport in bulk, this is allowed for some waste batteries but not for all of them, nor for all transport mode (land, sea, air) and it is always necessary verify if it is allowed by the rules in the states of departure, transit and destination.

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

212. 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.

213. 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. Waste batteries classed as hazardous 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, 2023)[70]; and (b) International Maritime Dangerous Goods Code (IMO, 2022)[71].

214. 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. Sorting and Storage

(a) Collection facilities

215. [Safe storage conditions have been extensively discussed in paragraph III.B.4]

216. Waste batteries entering a collection facility pending transfer to a disposal facility is an operation covered under Annex IV (D15 or R13). All batteries entering a small collection/storage facility, such as a garage or retailer should be checked to ensure that they are not damaged or leaking. They should also be checked for battery chemistry and separated accordingly to minimise the risks of any incidents and impact on the workers. The batteries should be stored upright in plastic acid-resistant leakproof bins that may simply be sealed and used as the transport container as well minimizing the risk of an accidental spillage. Those batteries leaking or damaged but not leaking, should be stored inside acid resistant leakproof containers (e.g., plastic bins/drums) to minimise risks to the environment and health in a designated storage area. Waste batteries 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 heavy metals. Effective acid neutralising spill clean-up materials should be available in the event of a spill incident.

217. The storage area should be located well away from areas of high risk to human health and the environment and 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 (e.g., sealed surface with acid resistant paint). Waste batteries 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. Access to the storage areas should be restricted to authorised personnel only wearing the appropriate PPE.

218. The number of waste batteries stored at the collection facility will depend on the volume handled by the establishment and the capacity of the storage area. Ideally batteries should be collected on a regular basis to avoid the need to store large quantities. Storage times should be kept to a minimum, for examples no longer than 60-90 days. The Commission for Environmental Cooperation[72] of North America has published some technical guidelines (2016) on WLAB.

(b) Disposal Plants

219. Waste battery disposal plants where they are recycled 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.

220. 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

[70] https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23.

[71] https://www.imo.org/en/publications/Pages/IMDG%20Code.aspx.

[72] http://www.cec.org/publications/environmentally-sound-management-of-spent-lead-acid-batteries-in-north-america/#:~:text=Given%20the%20ongoing%20and%20shared%20interest%20among%20Canada%2C,lead%20smelters%20and%20other%20facilities%20that%20process%20SLABs.

Commented [FC12]: China to streamline this section
Norway to better reflect the batteries described in the TGs and add reference to risks related to Lithium-ion batteries

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Norway to better reflect the batteries described in the TGs and add reference to risks related to Lithium-ion batteries

saleable products such as gypsum. The batteries should not be stored on bare ground or in uncovered areas to prevent soil and groundwater contamination.

221. 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.

222. Only authorized personnel wearing the appropriate PPE should be allowed to enter the waste storage area.

G. [Repair and repurpose of waste batteries for reuse]

H. Environmentally sound disposal

1. General considerations

223. 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.

224. Disposal operations relevant to waste batteries 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 reclamation of metals and metal compounds*);

(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*).

2. Pre-treatment

225. Depending on the type of battery, discharging the lithium battery is the first treatment step, followed by a dismantling step in the case of battery packs.

226. Dismantling allows the recovery of certain metals such as Al and steel from the casing, but also plastics, electronics and cables. Certain operators perform a thermal treatment step (pyrolysis), in some cases before dismantling.

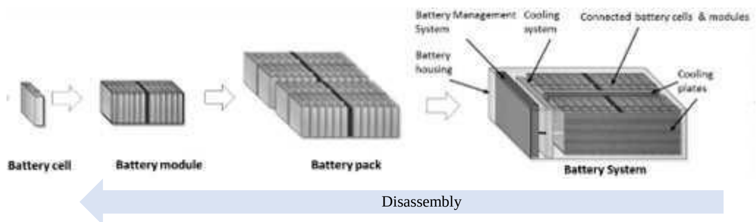


Figure12: Batterries disaseembly

227. The disassembly of the batteries involves returning to the single cell and is the reverse process of the assembly represented here.

228. To gain access to the black mass but also to recover other battery components, the battery undergoes mechanical stress in the form of crushing. Less common treatments are the solvent treatment and calcination. Crushing can be carried out in an inert atmosphere (N2, CO2, CO and Ar), in brine, or using other systems to prevent fire risks (e.g. air/gas removal from crushing chamber).

(a) Mechanical Separation[73]

229. Mechanical separation techniques are commonly used as the initial step in battery recycling processes. These techniques involve the physical separation of battery components based on their size, shape, and density. The main goal is to separate the metallic components, such as electrodes and current collectors, from non-metallic components, like plastic casings and electrolytes. The advantage of mechanical separation techniques is their ability to handle a wide range of battery types. However, these techniques do not recover metals in their pure form and often require further processing steps to refine and purify the materials.

230. A common mechanical separation technique is shredding, where batteries are broken down into smaller pieces to facilitate subsequent separation processes. Shredding can be followed by sieving, which uses screens with different mesh sizes to separate materials based on particle size. Magnetic separation [22] extracts ferrous components, while eddy current separation recovers non-ferrous metals based on conductivity.

231. Mechanical separation techniques have the flexibility to handle a wide range of battery types. However, these techniques do not recover metals in their pure form and generally represent an initial pretreatment step in a sequence of processing steps to refine and purify the target materials [22,32].

(i) Alkaline, NiCd and NiMH batteries[74]

232. In this case mechanical separation improves material purity for subsequent metallurgical extraction of target materials, such as zinc, manganese, cadmium, and nickel [22]

233. An example of a specialized mechanical process for the recovery of alkaline batteries is the one developed by Gasper et al. [32]. This process involves first shredding the batteries to uniform small sizes and then drying them at 425 ◦C in a rotary oven to remove moisture and evaporate any mercury present. The vaporized mercury is captured by a scrubber.

234. The dried material is then screened to create a fine fraction and a coarse fraction. The fine fraction contains the battery electrode powders and electrolyte powder, which can potentially be separated based on density differences using a gravity separator.

235. The coarse fraction undergoes magnetic separation to remove steel casing pieces, which are washed, briquetted, and sold as scrap steel. The remaining non-ferrous portion goes through gravity separation to recover brass, while plastics and paper float to the top for energy recovery.

236. The described mechanical separation process is designed to handle 1 metric ton per hour of spent batteries. This process offers a rate of 98% diversion from landfills, with a recovery rate of 87% of reuse of battery material [32]. While there is still an initial pre-processing step, this process shows how optimizing mechanical systems can improve metal enrichment before metallurgical processing.

(ii) Lithium-ion battery[75]

237. As for the alkaline batteries, shredding is the prevalent mechanical separation method, which breaks down batteries into smaller fragments to enable further sorting processes. While traditional mineral processing technologies can be applied, the pretreatment of LIBs presents unique challenges due to hazardous electrolytes, the risk of fire/explosion, and the diversity of cell/module designs [43] For this reason, cryogenic shredding techniques are being developed and studied [44]. After shredding, sieving can separate shreds according to size using screens with varying mesh apertures [45]. Magnetic separation is also used to divide ferrous substances from non-ferrous ones, since many batteries incorporate magnetic parts. Moreover, eddy current separation can sort non-ferrous metals from non-metallic materials based on their electrical conductivity. Sieving, magnetic separation, and eddy current separation can all be used in subsequent steps for separating non-metallic and non-ferrous metals from the target materials.

238. However, additional metallurgical processing remains necessary to extract the metals in their pure form.

(iii) [Black mass

Commented [FC14]: China to check the best position for the paragraphs on black mass

239. Black Mass is a waste obtained from the mechanical crushing of batteries and is sent to another plant for recycling. The composition of BM can vary significantly depending on the type of battery entering a recycling process, its chemistry and the recycling process itself. Exemplarily, with

[73] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.
[74] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.
[75] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.

an upstream or downstream thermal treatment, electrolytes and plastics may be oxidised completely, which are then no longer present in the black mass. Also the black mass can have a certain water content if the crushing of the batteries is performed under water. [76]

a. Black mass from waste lithium battery recycling[77]

240. The exact composition of black mass can vary significantly depending on the type of lithium-ion battery entering a recycling process, its chemistry and the recycling process itself. Exemplarily, with an upstream or downstream thermal treatment of the LIB or the black mass electrolytes and plastics may be oxidised completely, which are then no longer present in the black mass. Also the black mass can have a certain water content if the crushing of the batteries is performed under water. Table LIB-BM provides detailed information for black masses, recovered from lithium ion batteries and lithium iron phosphate batteries. Due to the very different composition, lithium ion batteries and lithium iron phosphate batteries are usually not recycled in the same recycling process. The table illustrates the composition of the black mass and its variability.

Black mass compounds	Hazard properties	BM1-LIB	BM2-LIB	BM3-LIB	BM4-LIB	BM5-LIB	BM6-LFP	BM7-LFP
		Weight (% total battery)						
Mixed metal oxides	see Table 5	10-75 %	-	-	-	-	-	-
Li-oxide		<10 %	-	-	<70%*	-	-	-
Li-, Ni-oxides		-	-	-		-	-	-
Li-, Co-oxides		-	1-50 %	-		-	-	-
Li-, Ni-, Co-, Al-oxides		-	1-50 %	-		-	-	-
Li-, Ni-, Co-, Mn-oxides		-	1-50 %	30-50 %		≥60 %	-	-
Li-, Fe-phosphate		-	-	-	-	-	≥60 %	60-70 %
Aluminium	not hazard	<10 %	-	<10 %	<10 %	<5 %	<5 %	<5 %
Copper	CAS No. 231-159-6 H411, Aquatic Chronic 2	<10 %	-	<5 %	<10 %	<5 %	<5 %	<2.5 %
Graphite	see Table 11	<40 %	30-50 %	25-40 %	10-40 %	<40 %	≤40 %	≤40 %
Potassium hydroxide (KOH), caustic potash	See Table 8	-	-	-	-	<5 %	-	-
Lithium fluoride	see Table 7	-	-	-	<5 %	-	<10 %	<10 %
PVDF	see Table 6	-	2-7 %	-	-	-	-	-
Lithium salts		-	1-4 %		<10 %	-	-	-
Organic solvents		-	-	5-10 %	-	-	-	-
Water	-	10-30%	-	-	-	-	-	-

*lithium carbonate: < 10 %; cobalt oxide: < 30 %; manganese oxide: < 15 %; nickel oxide: < 15 %

Table 21: Table LIB-BM: Chemical compounds and percentual share of black mass recovered from lithium-based batteries (LIB and LFP) with hazard identification according to CLP (Regulation (EC) No. 1272/2008) [78]

b. Black mass from waste alkaline battery recycling[79]

241. Due to the fact, that the alkaline batteries do not undergo a chemical change during the mechanical recycling process, the chemical compounds from the waste alkaline batteries define the characteristic of the black mass, see Table Alk-BM:

Chemical compounds		Weight percentages	CAS No.		Hazard statement code, hazard class and category code	
MnO_2	Manganese dioxide	25-50 %	1313-13-9	Harmonised C&L	H302 H332	Acute Tox. 4 Acute Tox. 4
ZnO	Zinc oxide	25-45 %	1314-13-2	Harmonised C&L	H400 H410	Aquatic Acute 1 Aquatic Chronic 1
Cu_2O	Dicopper oxide; copper (I) oxide	<5 %	1317-39-1	Harmonised C&L	H302 H318 H332 H400 H410	Acute Tox. 4 Eye Dam. 1 Acute Tox. 1 Aquatic Acute 1 Aquatic Chronic 1
SiO_2	Silicon dioxide	<5 %	7631-86-9	REACH registration C&L	-	not classified
KOH	Potassium hydroxide	<5 %	1310-58-3	Harmonised C&L	H302 H314	Acute Tox. 4 Skin Corr. 1A

[76] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.

[77] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

[78] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

[79] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

Table 22: Alk-BM: Chemical compounds and weight distribution of black mass recovered from alkaline batteries, with hazard identification according to CLP (1272/2008) [80]

3. Recycling

242. Recycling technologies play a crucial role in the sustainable management of battery waste and the recovery of valuable materials. Rechargeable batteries, such as nickel– cadmium (NiCd), nickel–metal hydride (NiMH), and lithium-ion (Li-ion), have become increasingly prevalent in modern society, powering a wide array of portable consumer electronics as well as electric vehicles. At the same time, single-use primary batteries based on alkaline chemistries continue to be widely utilized in lower-power devices. The growing production and utilization of these batteries also lead to increasing volumes reaching end-of-life each year. Effective recycling technologies are, therefore, crucial for recovering valuable materials from spent batteries and reducing the environmental impacts associated with disposal. Among battery waste we have to consider is the Battery Manufacturing Waste, the materials or objects rejected during the battery manufacturing process, which cannot be re-used as an integral part in the same process and need to be transported to be recycled in sites other than those of production.

243. All currently used systems combine mechanical, hydrometallurgical, and pyrometallurgical processing steps in various arrangements, despite the distinct target materials contained in each battery type. [81] However, substantial differences exist in the specific operating parameters, equipment utilized, and procedural details applied for recycling the different battery types.

244. Pyrometallurgy utilizes high temperatures to extract metals from battery materials, batteries are subjected to thermal treatment, such as smelting or roasting, to decompose organic binders, burn off organic electrolytes, and convert metal compounds into a molten or gaseous state.

245. Hydrometallurgical processes involve the use of aqueous solutions to extract metals from battery materials. These processes rely on chemical reactions to dissolve metals into a solution, followed by separation and purification steps to recover the metals. Hydrometallurgical processes offer the advantage of selective metal recovery and can be tailored to specific battery chemistries. However, they often require complex chemical processes and generate significant volumes of wastewater, which need to be properly treated to avoid environmental contamination.

246. Biotechnological approaches, also known as bioleaching, utilize microorganisms to extract metals from battery materials. Certain bacteria, fungi, and archaea possess the ability to selectively leach metals from various sources, including battery components.

247. Direct recycling aims to reclaim and restore the functionality of battery components instead of fully breaking down batteries into metals. The goal is to reduce processing steps and material losses. This optimized direct recycling approach avoids the costs and waste of fully resynthesizing the active material.

(a) Lithium based batteries

248. The figure gives an overview on the recycling steps and recycling approaches for lithium batteries as well as the material flows from the different recycling steps or approaches. A distinction is made between material flows that are under scope (relevant material flows) and other material flows. In the case of other material flows, it is assumed that they are either not a waste flow (e.g. having been recycled into a product, or destined for recovery) or that they fit under already existing entries in the list of waste, under different, non-battery specific categories. Relevant material flows are therefore both battery-specific and not currently classified specifically. Detailed and recent surveys on the recycling of lithium batteries can be found in dedicated studies (ASYS 2022; Latini et al. 2022; Wu, Kaden, and Dröder 2023; Yu et al. 2021; Zhang et al. 2021). [82]

[80] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[81] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.
[82] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

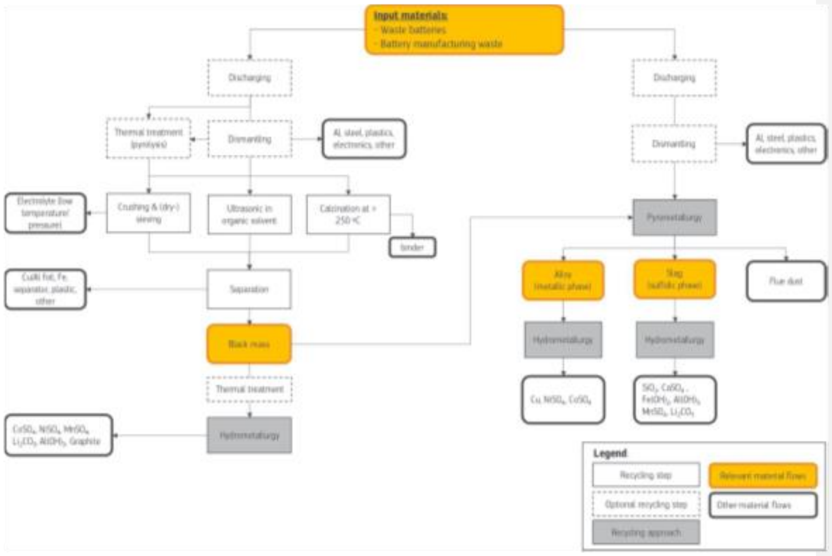


Figure 13: Simplified flow-chart of mechanical (left) and pyrometallurgical (right) lithium battery recycling processes [83]

(b) Nickel based batteries

249. Vacuum distillation is a proven approach to recycle Ni-Cd batteries and can also be used for NiMH batteries. In a first step, a furnace is evacuated to 0.1 mbar with oven temperature of 100 to 150 °C. This is followed by further heating to 750 °C. In the furnace remains a nickel-iron mixture and an oil-water mixture. The nickel-iron mixture is separated and can be passed on to steel manufacturers (Accurec 2023). In a second known recycling process, the batteries are first opened in a cutting mill. The batteries are then mixed with other nickel-containing waste and can be used as a master alloy for the production of stainless steel (Holmberg 2017) [84]. Industrial Ni-Cd battery recycling predominantly employs high-temperature pyrometallurgical processes above 1000 ◦C. [85]

250. NiMH batteries contain significant amounts of rare earth elements (REEs), like lanthanum, cerium, neodymium, and praseodymium, along with nickel, cobalt, and other metals [34]. Pyrometallurgical treatments are usually insufficient to extract marketable REEs from waste NiMH since they result in a mixture of REEs in a slag form [34]

251. Hydrometallurgical processes involve the use of aqueous solutions to extract metals from battery materials. Leaching [33,36] is a common hydrometallurgical process used in battery recycling. It involves the use of acid or alkaline solutions to dissolve metals from the battery materials.

[83] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

[84] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

[85] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.

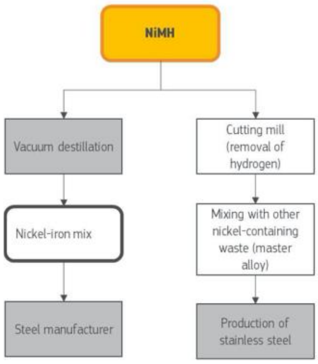


Figure 14: Simplified flow-charts for nickel-cadmium and nickel-metal-hydride battery recycling. [86]

(c) Sodium based batteries

(i) Sodium ion

(ii) High Temperature Sodium Nickel Chloride (NaNiCl)

252. Completely discharged and dismantled Na-NiCl batteries are sliced and soluble components, such as NiCl2, NaCl, and NaAlCl are leached out. These soluble components are further separated by precipitating the nickel as nickel sulphide, and by the subsequent crystallisation of NaCl and NaAlCl from the solution. The insoluble case material and ceramics undergo mechanical sieving and magnetic separation, and the valuable metals are recovered for metallurgical processing and subsequent reuse. The relatively expensive beta alumina ceramic electrolyte is currently not recycled (Armand et al. 2023). [87]

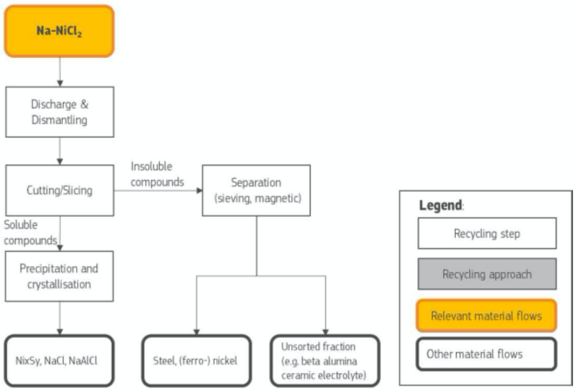


Figure 15: Simplified flow-charts for sodium-nickel-chloride battery recycling. [88]

(iii) High temperature Sodium Sulphur (NaS)

(d) Alkaline batteries[89]

253. Alkaline batteries can be recycled together with carbon based batteries in a smelting process. The alkaline battery is shredded or cut and the active materials are removed from the internal casing by mechanical force (e.g. chain disrupter). On a vibrating screen the active materials and the casing are separated into two different fractions. With further separation techniques, the two fractions

[86] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[87] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[88] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.
[89] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

paper/plastic and iron can be recovered. The resulting zinc- and manganese- rich black mass can be recycled in pyrometallurgy and hydrometallurgy recycling processes. Black mass recovered from alkaline batteries can also be used as fertilisers for plants, given the presence of the micronutrients zinc and manganese (Tracegrow 2023).

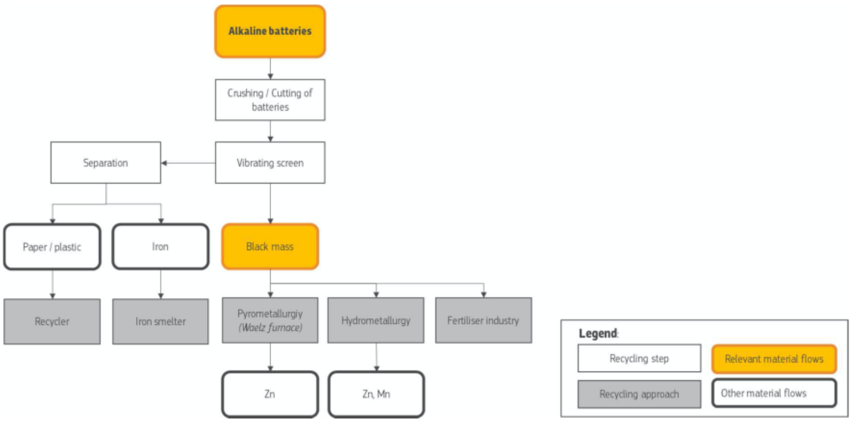


Figure 16: Simplified flow-chart of alkaline battery recycling. [90]

(e) Zinc batteries

254. Zinc-based batteries can be recycled either mechanically or with pyrometallurgical processes. With mechanical recycling, the aim is to recover a zinc- and manganese- rich black mass. To gain access to the black mass, the batteries undergo as a first step a mechanical stress in the form of crushing or cutting. From the black mass bearing fine fraction, magnetic metals are removed. The coarse fraction is further treated to recover steel alloy, non-ferrous materials, paper and plastic. [91]

255. Roasting between 500–800 ◦C can remove moisture and decompose metal compounds, like MnO2 to oxides or reduced species[92]. Direct smelting above 1000 ◦C separates Zn and Mn metals from slag but has issues, like Zn losses [33]. Thermal desorption can selectively vaporize and recover mercury (if present) at 300–500 ◦C without extensive heating [22].

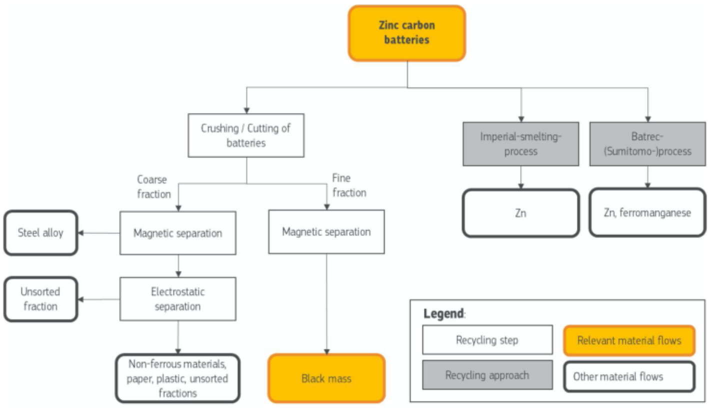


Figure 17: Simplified flow-chart of mechanical (left) and pyrometallurgical (right) zinc battery recycling processes. [93]

[90] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

[91] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

[92] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.

[93] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

(f) Battery manufacturing waste[94]

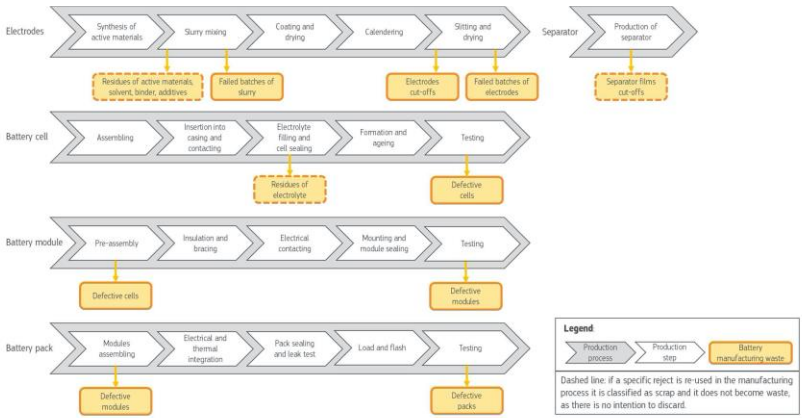
256. Battery manufacturing waste is defined in [the legislation of a group of Parties, for example in EU at] Article 3 (51) of the Battery Regulation as “the materials or objects rejected during the battery manufacturing process, which cannot be re-used as an integral part in the same process and need to be recycled”. The battery manufacturing process can be divided in different sub-processes from the synthesis of active materials for electrode production up to the assembly to the battery pack.

257. Possible rejects that can be generated in the electrode production are residues of active materials, solvent, binder, additives (in the mixing process) and electrode cut-offs (in the slitting process). Failed batches of slurry and electrodes could also be generated. In the separator production film cut-offs can be generated. Typical rejects of the battery cell production are residues of electrolyte (in the electrolyte filling process) and defective cells (after testing).

258. When assembling cells in the battery module production process, defective cells can be detected and discarded. Modules that do not fulfil the given quality requirements can also be disposed of by the manufacturer.

259. Finally, in the battery pack production process, defective modules can be identified during assembly and defective packs can be identified during the final testing. Hence waste streams from battery manufacturing considered in the scope include:

- Residues of active materials, solvent, binder, additives and failed batches of slurry
- Electrode cut-offs and failed batches of electrodes
- Separator film cut-offs
- Residues of electrolyte
- Defective cells, modules and packs.



Source: based on (Liu et al. 2021; VDMA 2023)

Figure 18: Simplified flow-chart of the battery manufacturing process and the related battery manufacturing waste [95]

260. Rejects that are re-used in the manufacturing process do not become waste.

4. Final Disposal

Battery Type	Recycling Technology	Advantages	Disadvantages
Alkaline, Ni-Cd, Ni-MH	Mechanical separation	Can handle diverse battery types and chemistries Separates metals from non-metals Scalable and flexible process	Does not recover pure metals Further refining steps needed Dismantling and size reduction required first

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[94] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

[95] Support for the new batteries regulatory framework - JRC, November2023- preliminary draft not yet published.

Battery Type	**Recycling Technology**	**Advantages**	**Disadvantages**
	Pyrometallurgy	Effective for large-scale metal recovery	High energy consumption Hazardous emissions Slag waste generation
	Hydrometallurgy	Selective metal recovery High purity products	Multi-stage, complex processes High reagent consumption Effluent treatment required
Lithium-Ion	Mechanical separation	Can handle diverse battery types and formats Separates metallic and non-metallic materials Facilitates further processing	Does not recover pure metals or compounds Further refining steps needed Pre-processing and size reduction required first
	Pyrometallurgy	High throughput capability	High energy consumption Hazardous emissions Material losses to slag
	Hydrometallurgy	Selective recovery of materials High purity products	Complex multi-stage processes High reagent consumption Effluent treatment requirements
All Battery Types	Biotechnological Methods	Environmentally friendly Energy efficient Selective leaching	Early development stage Process optimization required
All Battery Types	Direct Recycling	Reduces processing steps Maintains material value	Limited commercial viability currently

Table 23: Summary of recycling technologies for different types of batteries. [96]

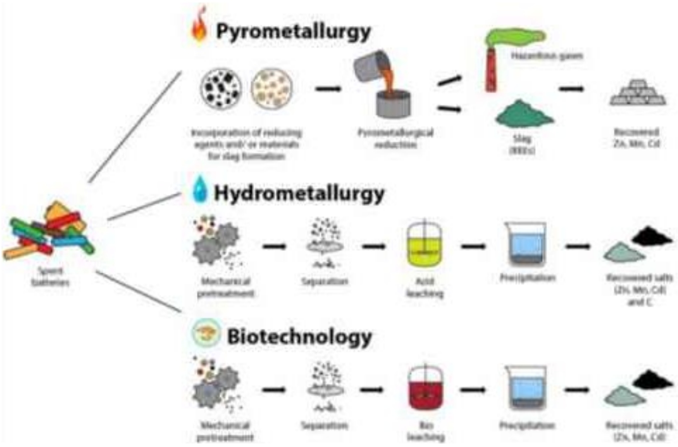

Figure 19: Typical pyrometallurgical, hydrometallurgical, and biotechnological recycling methods for the recovery of spent Alkaline, Zinc and Nickel based batteries[97]

[96] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.

[97] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.

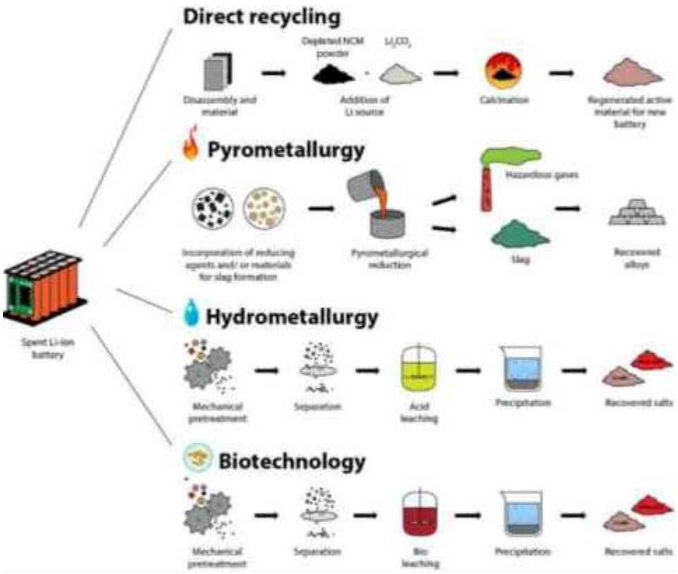

Figure 20: Typical direct, pyrometallurgical, hydrometallurgical, and biotechnological recycling methods for the recovery of Li-ion battery active materials. [98]

[H bis Pollution Control]

I. Health & Safety

1. General considerations

261. Recycling batteries helps protect the environment by preventing the heavy metals and hazardous chemicals contained in batteries from leeching out into the environment[99]. However, these potential hazards for the environment also pose hazards for workers at facilities that recycle batteries. Workers who will be taking part in operations to recycle batteries must be aware of the hazards and have proper equipment and training to provide protection from the hazardous substances.

(a) Sampling and analysis[100]

262. Chemical sampling and analysis is used by occupational health and safety professionals to assess workplace contaminants and associated worker exposures. The validity of an assessment is based, in part, on the procedures used for sample collection and analysis, and data interpretation. In many instances these procedures use approaches that have been refined over many years and are accepted by the professionals as good practice. However, the multitude of variables within a specific workplace require the professional to exercise judgment in the design of a particular assessment.

(b) Laboratory accreditation and certification

263. Participation in accreditation and certification programs allow laboratories to compare themselves against other laboratories and against accepted standards. Most programs require participation in a performance evaluation testing program where samples of unknown concentration are analyzed and reported to an independent body. Many programs require an on-site assessment by a trained quality assessor. Successful participation in an accreditation or certification program is an indicator that a laboratory operates under a functioning quality assurance program.

Commented [FC16]: China to reflect what kind of environmental impact should be included in this chapter . Reference is to chapter 1 b.

Commented [FC17]: EU to review to make sure it is relevant for owbs, to see if the new J section in WLAB TGs.
Canada to streamline the section
China support to EU and Canada

[98] *Energies* **2023**, *16(18)*,6571. https://doi.org/10.3390/ en16186571.
[99] https://www.osha.gov/green-jobs/recycling/batteries.
[100] https://www.osha.gov/sampling-analysis.

264. Laboratories analyzing samples should have a documented quality management system. This system should address topics such as:

(a) Organization of the Management System;

(b) Control of Documents, Data and Records;

(c) Purchasing;

(d) Corrective and Preventive Action;

(e) Internal Audits;

(f) Selection and Training of Personnel;

(g) Selection of Analytical Methods;

(h) Quality Assurance and Estimation of Uncertainty;

(i) Equipment and Instrumentation;

(j) Traceability of Standards and Materials;

(k) Reporting of Results.

2. Electrical dangers

265. Considering the treatment and recycling operations of batteries that may still have residual charge, particular attention must be paid to the training and provision of equipment suitable for working safely at high voltage. Only qualified Expert Person can carry out electrical work, a person who has adequate education, knowledge and relevant experience to enable him or her to analyze the risks and avoid the dangers that electrical work can cause. We recommend the use of international standards for prevention and protection, such as ICS 13.260 Protection against electric shock. Live working (including tools for working with voltages) and EN 50110-1:2014-01.

3. Toxic & health effects

(a) Provisional description of main constituents' properties

(i) Cadmium

266. Cadmium (Cd) is a soft, malleable, bluish white metal found in zinc ores, and to a much lesser extent, in the cadmium mineral greenockite. Most of the cadmium produced today is obtained from zinc byproducts and recovered from spent nickel-cadmium batteries[101].

267. Common industrial uses for cadmium today are in batteries, alloys, coatings (electroplating), solar cells, plastic stabilizers, and pigments. Cadmium is also used in nuclear reactors where it acts as a neutron absorber.

268. Cadmium and its compounds are highly toxic and exposure to this metal is known to cause cancer and targets the body's cardiovascular, renal, gastrointestinal, neurological, reproductive, and respiratory systems.

269. Workers can be exposed to cadmium by breathing in dusts, fumes, or mists containing cadmium. Cadmium or cadmium compounds can also get on the skin, contaminate clothing or food, and be ingested (which is also one of the routes of exposure)

270.

(ii) Cobalt

271. As a component of vitamin B12, cobalt (Co) is an essential metal. However, high levels of cobalt lead to metallosis, characterized by sensorineural hearing loss, visual and cognitive impairment and peripheral neuropathy[102] Excessive serum cobalt may arise from a variety of sources, including diet, exposure from industrial fabrication, or from alloys used in tooth and hip joint replacements.

(iii) Manganese

272. Mn is an essential trace element for human normal developments and functions. As an enzyme co-factor or activator for metabolic reactions such as Mn-superoxide dismutase (Mn-SOD), Mn is also

[101] https://www.osha.gov/cadmium.

[102] Redox toxicology of environmental chemicals causing oxidative stress, Redox Biology, 2020.

required. However, excessive Mn causes primarily neurotoxicity, characterized by Parkinsonism-like symptoms with degeneration of dopaminergic neurons in the basal ganglia[103]

(iv) Nickel

273. Nickel (Ni) is a hard, silvery-white metal that may cause irritation to the skin. Exposure can harm the lungs, stomach, and kidneys.[104] Exposure to nickel may lead to cancer. Workers may be harmed from exposure to nickel. The level of exposure depends upon the dose, duration, and work being done.

274. Nickel is used in many industries. It's used to make stainless steel and other metal alloys. Some examples of workers at risk of being exposed to nickel include the following:

(a) Refinery workers in nickel processing plants;

(b) Jewelry and pawn shop workers who come in contact with nickel coins or jewelry;

(c) Factory workers in plants where nickel alloys are used;

(d) Workers who come in contact with tools and other nickel releasing surfaces.

(v) Zinc

275. Zinc's effectiveness in protecting steel against corrosion by galvanising is well recognised, while its ability to die cast complicated components makes zinc indispensable in a multitude of industry and household products. It also has important markets in the brass and construction industries and in chemicals and constitutes an essential nutritional element[105].

276. Zinc is necessary for the function of a large number of metalloenzymes[106]. These enzymes include alcohol dehydrogenase, alkaline phosphatase, carbonic anhydrase, leucine aminopeptidase, superoxide dismutase, and deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) polymerase. As such, zinc is required for normal nucleic acid, protein, and membrane metabolism, as well as cell growth and division. Zinc also plays an essential role in the maintenance of nucleic acid structure of genes (zinc finger phenomenon). Zinc deficiency has been associated with dermatitis, anorexia, growth retardation, poor wound healing, hypogonadism with impaired reproductive capacity, impaired immune function, and depressed mental function; increased incidence of congenital malformations in infants has also been associated with zinc deficiency in the mothers (Cotran et al. 1989; Elinder 1986; Sandstead 1981).

277. Just as zinc deficiency has been associated with adverse effects in humans and animals, overexposures to zinc also have been associated with toxic effects. the toxic effects that have been associated with exposures to high levels of zinc, depending by the inhalation, oral, and dermal routes, in particular for zinc chloride, zinc oxide, zinc sulphate, and zinc sulphide.

278. Zinc Oxide. Metal fume fever, a well-documented acute disease induced by intense inhalation of metal oxides, especially zinc, impairs pulmonary function but does not progress to chronic lung disease (Brown 1988; Drinker and Drinker 1928; Malo et al. 1990). Symptoms generally appear within a few hours after acute exposure, usually with dryness of the throat and coughing (Drinker et al. 1927b). The most prominent respiratory effects of metal fume fever are substernal chest pain, cough, and dyspnea (Rohrs 1957). The impairment of pulmonary function is characterized by reduced lung volumes and a decreased diffusing capacity of carbon monoxide (Malo et al. 1990; Vogelmeier et al. 1987). The respiratory effects have been shown to be accompanied by an increase in bronchiolar leukocytes (Vogelmeier et al. 1987). The respiratory symptoms generally disappear in the exposed individual within 1–4 days (Brown 1988; Drinker et al. 1927b; Sturgis et al. 1927). Inhalation of zinc oxide is most likely to occur in occupational situations where zinc smelting or welding take place. Ultrafine zinc oxide particles (0.2–1.0 μm) originate from heating zinc beyond its boiling point in an oxidizing atmosphere. Upon inhalation, these small particles (<1 μm) reach the alveoli and cause inflammation and tissue damage in the lung periphery (Brown 1988; Drinker et al. 1927b; Vogelmeier et al. 1987).

[103] Redox toxicology of environmental chemicals causing oxidative stress, Redox Biology, 2020.

[104] https://www.cdc.gov/niosh/topics/nickel/.

[105] https://www.ilzsg.org/what-is-zinc/.

[106] https://www.ncbi.nlm.nih.gov/books/NBK600535/#ch3.s2.

(vi) Graphite

279. It is a mineral consisting of carbon. Graphite[107] has a greasy feel and leaves a black mark, thus the name from the Greek verb *graphein*, “to write. It has a layered structure that consists of rings of six carbon atoms arranged in widely spaced horizontal sheets, graphite thus crystallizes in the hexagonal system and is very soft because the individual layers of carbon atoms are not as tightly bound together as the atoms within the layer. It is an excellent conductor of heat and electricity.

280. Graphite is used in pencils, lubricants, crucibles, foundry facings, polishes, brushes for electric motors, and cores of nuclear reactors. Its high thermal and electrical conductivity make it a key part of steelmaking, where it is used as electrodes in electric arc furnaces. In the early 21st century, global demand for graphite has increased because of its use as the anode in lithium-ion batteries for electric vehicles.

281. Graphite pneumoconiosis is a well-recognized pulmonary lesion that is found in workers involved in the mining and processing of graphite. Lungs diseased by graphite inhalation manifest characteristic pathological features[108].

282. In humans chronically exposed to graphite, graphite pneumoconiosis might develop. The condition is characterized by a granulomatous reaction, interstitial fibrosis, and vascular sclerosis. However, these changes are believed to be due to impurities, particularly silica, in the graphite dust that is mined (Gloyne et al. 1949; Harding and Oliver 1949; Hanoa 1983). Acute and sub chronic exposure (up to 13 weeks) studies in animals involving inhalation exposure to graphite, with or without the concomitant presence of fog oil, showed only minimal inflammatory reactions in the respiratory tract. The inflammation was fully reversible most of the time. However, if graphite particles persist in the lung, epithelia of the terminal bronchioles and alveoli show signs of hyperplasia, and graphite-containing granulomas are found in lymphoid tissue. In vitro, graphite has minimal cytotoxicity and no mutagenic activity.

(b) Occupational Exposure Limits (OEL)

	TLV				BEI	
	ACGIH[109]		EUROPEAN UNION[110]		ACGIH	
	TWA	TWA	TWA	TWA		
	Inhalable fraction	Respirable fraction	Inhalable fraction	Respirable fraction	In blood	In urine
	mg/m³	mg/m³	mg/m³	mg/m³	µg/L	µg/L
Cadmium	0.01	0.002	0.004 (until 11.07.2027) -------------------- 0.001	0.004 (until 11.07.2027) (*)	5	5 µg/g creatinine
Cobalt	0.02		Under discussion			15
Manganese	0.1	0.02	0.2	0.05		
Nickel			0.1 ------------ 0.05 (from 18.01.2025)	- ------------- 0.01 (from 18.01.2025)		
Elemental	1.5					5
soluble inorganic compounds	0.1					30
insoluble inorganic compounds	0.2					5
Zinc oxide	-	2 (10 STEL)				
Graphite	-	2				

Table 24: Provisional table of occupational exposure limits (*) Respirable fraction in those Member States that implement a biomonitoring system with a biological limit value not exceeding 0,002 mg Cd/g creatinine in urine.

[107] https://www.britannica.com/science/graphite-carbon.

[108] https://www.ncbi.nlm.nih.gov/books/NBK224564/.

[109] Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) - ACGIH 2024.

[110] https://echa.europa.eu/legislation-finder.

(i) Definitions

283. ACGIH means American Conference of Governmental Industrial Hygienists

284. TLV means Threshold Limit Value:

It refers to airborne concentrations of chemical substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects.

285. TLV-TWA means Threshold Limit Value–Time-Weighted Average:

286. The TWA concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect.

287. TLV-STEL means Threshold Limit Value–Short-Term Exposure Limit:

288. a 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLV-TWA.

289. BEI means Biological Exposure Indices: mg/m3 means milligrams per cubic metre of air at 20 °C and 101,3 kPa (760 mm mercury pressure).

290. ISO 7708:1995(en) Air quality — Particle size fraction definitions for health-related sampling

(a) inhalable fraction: mass fraction of total airborne particles which is inhaled through the nose and mouth;

(b) respirable fraction: mass fraction of inhaled particles which penetrate to the unciliated airways.

(ii) About ACGIH

291. The American Conference of Governmental Industrial Hygienists (ACGIH®) is a private, not-for-profit, nongovernmental corporation whose members are industrial hygienists or other occupational health and safety professionals dedicated to promoting health and safety within the workplace. ACGIH is a scientific association. ACGIH is not a standards-setting body.

292. ACGIH is a 501(c)(3) charitable scientific organization that advances occupational and environmental health. The organization has contributed substantially to the development and improvement of worker health protection. The organization is a professional society, not a government agency.

293. The Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) are developed by ACGIH as guidelines to assist in the control of health hazards. These recommendations or guidelines are intended for use in the practice of industrial hygiene, to be interpreted and applied only by a person trained in this discipline.

294.

(iii) Threshold Limit Values for Mixtures[111]

295. Most threshold limit values are developed for a single chemical substance. However, the work environment is often composed of multiple chemical exposures both simultaneously and sequentially. It is recommended that multiple exposures that comprise such work environments be examined to assure that workers do not experience harmful effects.

296. There are several possible modes of chemical mixture interaction.

(a) Additivity occurs when the combined biological effect of the components is equal to the sum of each of the agents given alone;

(b) Synergy occurs where the combined effect is greater than the sum of each agent;

(c) Antagonism occurs when the combined effect is less.

297. When two or more hazardous substances have a similar toxicological effect on the same target organ or system, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, different substances should be considered as additive where the health effect and target organ or system is the same.

[111] Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) - ACGIH 2024.

298. That is, if the sum of

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots \frac{C_n}{T_n}$$

299. exceeds unity, the threshold limit of the mixture should be considered as being exceeded (where C1 indicates the observed atmospheric concentration and T1 is the corresponding threshold limit.

300. Exceptions to the above rule may be made when there is a good reason to believe that the chief effects of the different harmful agents are not additive. This can occur when neither the toxicological effect is similar nor the target organ is the same for the components. This can also occur when the mixture interaction causes inhibition of the toxic effect. In such cases, the threshold limit ordinarily is exceeded only when at least one member of the series (C1/T1or C2/T2, etc.) itself has a value exceeding unity.

301. Another exception occurs when mixtures are suspected to have a synergistic effect. The use of the general additive formula may not provide sufficient protection. Such cases at present must be determined individually.

302. The additive formula applies to mixtures with a reasonable number of agents. It is not applicable to complex mixtures with many components (e.g., gasoline, diesel exhaust, thermal decomposition products, fly ash, etc.).

(iv) Nanomaterials[112]

303. Nanomaterials are objects that are 100 nm or smaller in one or more dimension.

304. Substances composed of nanomaterials, even when agglomerated, may have greater or different toxicity than the same substance in fine or sometimes called “bulk” form.

305. When supported by the literature, ACGIH may differentiate TLVs for nanomaterials. Currently there are no substances with TLV for nanomaterials.

4. Prevention & control

306. The key to controlling employees and contractors exposure in the workplace is to ensure there is a comprehensive health and safety programme in place to protect the health of everyone and prevent the spread of contamination to others outside the workplace. Such a programme and measures include the following:

(a) There are effective engineering controls and maintenance/monitoring programmes in place to minimise and control the presence of 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) There are established workplace practices, documented programmes, and standard operating procedures in place to minimise the risk of exposure these include housekeeping and hygiene controls, sweeping and cleaning measures and equipment and ensuring that all employees/contractors have been properly trained in what to do in the workplace and the procedures to follow. Regular monitoring/auditing of workplace practices and procedures is important to ensure these are being effectively followed;

(c) The provision of Personal protection equipment (PPE e.g., overalls, socks, jackets, shirts, safety boots (including chemical resistant), standard or chemical resistant aprons/clothes gloves, helmets, safety glasses, face shields, hearing protection) and respiratory protection equipment (RPE e.g., face masks with appropriate assigned protection factor) to minimise exposure to contaminants;

(d) The provision of employee/contractor training/retraining programmes on contaminants management measures. Specific education and awareness materials should be provided to employees/contractors and also their families. Providing employee specific counselling and where appropriate retraining for those with an elevated presence of contaminants in blood or urine. This is important given the significant role that employee behaviour and personal hygiene plays in causing elevated contamination levels in the organism;

[112] Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) - ACGIH 2024.

(e) Ensuring effective personal hygiene measures are in place including, daily changes of work clothing/uniform or more frequently if dirty, removing contaminated clothing/PPE before entering a clean area (e.g., canteen, office's, etc.), requiring anyone exposed to contaminants to shower, scrub their nails and wash hands, arms, face, hair and brush their teeth at the end of the working day before putting on their own clean clothing, no contaminated work clothing to be taken home to wash (all workplace clothing to remain and preferably washed on site to reduce the risk of the spread of lead contamination offsite);

(f) To minimise the risk of elevated contaminants 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, as for contaminants a the possible route of penetration into the organism is represented by ingestion, do not have facial hair that adversely affects the use of RPE and wear their respiratory protection in the workplace;

(g) Under ILO Conventions children under the age of 18 are prohibited from hazardous work and so should be prohibited from entering or working in a OWB treatment/recycling plant.

5. Engineering controls

307. Effective engineering controls should be regarded as the first line of control in minimising the risk of workers and others (e.g. employee family members and contractors) of being exposed to contaminants 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 the correct use of personal protective equipment to reduce the risk of exposure.

308. Engineering controls 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 l contaminants fume and dust in the work area (e.g., installing Local Exhaust Ventilation (LEV) systems, air filtration systems);

(d) Automating tasks so workers no longer need to perform them;

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

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

309. The use of engineering controls in the recycling plant is an essential and represents the most effective approach to reduce and control the levels of contaminants present in the work area and minimise the risk to employees. It is essential that the controls are regularly maintained and that there is an ongoing preventative maintenance programme to ensure they continue to operate as designed.

310. Where feasible design the facility, equipment, or process to remove the hazard and/or substitute something that is not hazardous or is less hazardous, for example by:

(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 ensure there are low contaminants in air levels.

311. 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.

312. 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 free from contaminants.

313. For existing OWB recycling plants or for the conversion of existing WLAB recycling plants to OWB, 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 black mass storage and handling and ways of reducing contaminants becoming airborne;

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

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

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

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

6. Housekeeping

314. A clean plant is essential for minimising contaminants exposure and is as important as emission controls and hygiene measures.

315. 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, sweeping or use of compressed air lines should not be used because of dust generation and spread of contamination. Any residues from housekeeping should be collected and returned to feedstock.

316. Contaminated plant, equipment, containers, and tools, used for example by contractors, should be decontaminated, by approved methods (e.g. washing with suitable solvents such as water), 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. Contaminated water should be collected, analyzed and treated o discharged to the wastewater treatment plant is present.

317. High standards of cleanliness should be adopted to minimize the spread of contaminants and regular workplace checks should be carried out to monitor the effectiveness of the housekeeping measures.

318. Within a plant there are a number of locations other than treatment/recycling 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 concentration of contaminants in air for exposure and also swab testing to check the effectiveness of housekeeping. The swab/dust wipe testing of surfaces for lead should include tables, chairs, window ledges, cabinets, etc.

7. Personal protection equipment

319. It is important that employees/contractors work use personal protection equipment (PPE) to minimise their risk to lead exposure wherever technical or organisational measures are not feasible or not sufficient. However, employers should not rely on PPE alone to control exposure to contaminants where other effective control options are also available. PPE can be effective, but only when workers/contractors use it correctly and consistently and if it is properly maintained. 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.

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

321. Each company should have site-specific documented procedures and PPE/RPE 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/RPE is to be worn, type of equipment to be worn, issuance of PPE/RPE and maintenance and cleaning of PPE/RPE. There should be part of a comprehensive training programme for the safe use of the equipment.

322. 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.

323. Considering the treatment and recycling operations of batteries that may still have residual charge, particular attention must be paid to the provision of equipment suitable for working safely at high voltage.

324. PPE requirements should be established for specific workplace activities (e.g. hot metal work, dismantling EV batteries, 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 (e.g. eye & hearing protection);

(g) Tools for working with voltages.

325. 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) Apron (standard or acid resistant);

(f) Workplace footwear (e.g., leather metatarsal boots, wellington boots with steel toecaps, acid resistant);

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

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

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

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

(k) Respiratory protection equipment.[113] Selection of an appropriate respirator type must be a result of a risk assessment to determine the minimum assigned protection factor (APF);

(l) Gaiters;

(m) Hearing protection;

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

(o) Jackets and body warmers;

(p) Waterproofs.

326. 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).

[113] (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.).

327. 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.

328. 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).

329. 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 contaminants.

8. Medical Surveillance

(a) Practical recommendations for the health surveillance of workers[114]

330. Health surveillance of workers must be carried out in accordance with the principles and practices of occupational medicine; it must include at least the following measures:

(a) keeping records of a worker's medical and occupational history;

(b) a personal interview;

(c) where appropriate, biological surveillance, as well as detection of early and reversible effects.

331. Further tests may be decided upon for each worker when he is the subject of health surveillance, in the light of the most recent knowledge available to occupational medicine.

332. The doctor and/or authority responsible for the health surveillance of workers exposed to carcinogens, mutagens or reprotoxic substances must be familiar with the exposure conditions or circumstances of each worker.

J. Emergency response plans

1. Emergency planning

333. The operation of a waste recycling plant involves various risks, such as fires (e.g. battery storage areas, bag houses, furnace explosions/fires), stormwater and effluent overflows, etc. These all present the risk of releases of hazardous substances and this should be considered/included as part of the planning. Given the risks of operation it is important that its operations and activities are reviewed and all areas where there are risks 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 recycling plant would be regarded as a major accident hazard and there are specific requirements regarding the preparation of emergency plans for incidents.

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

335. 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.

336. The 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;

[114] European Agency for Safety and Health at Work, *Carcinogens at work*, Publications Office of the European Union, 2019, **https://data.europa.eu/doi/10.2802/22110**.

(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;

(h) emergency communications equipment (e.g. radios, telephones).

337. 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

338. 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;

(h) Site plan highlighting key areas/risks.

339. 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.

340. 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.

341. Copies of the emergency plan should be readily available for use by the emergency services in the event of an emergency and updated on a regular basis, at least once per year or whenever significant changes occur.

3. Emergency response training

342. 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 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

343. 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 up-to-date 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 the planning of programmes, the development of legislation, the review of documents and data and decision making on local issues related to waste batteries. 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.

K. Management of Contaminated sites

1. Identification, investigation and assessment

344. Soil 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. A number of countries have established levels of contaminants present in soils which if exceeded result in them being classified as contaminated.

345. Sites where 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 soil and groundwater is contaminated, what contaminants are present and their levels to assess what further action, if any, needs to be undertaken.

346. The site assessment should establish what operations occurred on the site, a location plan of the operations and possible areas of concern (e.g., waste battery 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.

347. 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.

348. A risk assessment should then be prepared setting out the nature and extent of contamination, the risks it may pose, the routes of impact 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 soil 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[115], UK, Netherland[116]) to assess contamination levels and acceptable use values.

349. Following these stages an environmental impact assessment report (Action Plan) 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 soil can be used for, description of the works, if any, needed to rectify the impact. This 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. Waste batteries site decommissioning

350. The process for closure and decommissioning of a waste battery site broadly falls into five distinct phases:

[115] California EPA, https://oehha.ca.gov/risk-assessment/sites.

[116] Dutch Intervention values; https://www.pbl.nl/sites/default/files/downloads/711701023.pdf.

(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, including hazardous wastes inventory, 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, this includes decontamination and demolition of buildings and equipment, management and disposal of materials generated during decommissioning, dust control and monitoring, site clean-up and soil remediation);

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

351. 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.

L. Public participation

352. 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 battery wastes, the planning of programmes, the development of legislation, the review of documents and data and decision making on local issues related to waste 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.

353. 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.

354. Public awareness and attitudes to waste batteries 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.

355. Raising public awareness and promoting public participation is especially critical for the ESM of waste batteries other than WLAB.

356. Local authorities should organize awareness raising campaigns/events addressed to business and the public to make people aware of the importance of ESM of waste batteries other than WLAB in tackling environmental problems such as 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 waste batteries management;

(e) Frame waste batteries management activities as a topic of great interest for voters, particularly on important issues (e.g., price of valuable substances, pollution);

(f) Increase visibility and credibility of good waste batteries 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).

357. In many jurisdictions the public should 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 should 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.

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Appendix

Generic name and information (when available)	Possible constituents and, when informed, Hazard characteristics Potential categorization Annex I (if identified) Annex II (just those identified, may have any other)	Complementary information of interest (not exhaustive). Extracted from available SDS * Regarding D10 and D5, we consider important to the SIWG to validate if feasible.	Transport regulation (extracted from available SDS)	Are there technologies for material recovery? (Yes/No)
Li-ion ($LiPF_6$) Rechargeable Cylindric/prism	Lithium Hexafluorophosphate (Electrolyte Salt) Includes one or more of the (Solvent of the Electrolyte): Ethylene carbonate Propylene Carbonate, Diethyl Carbonate, Ethyl Propionate and Polyvinyl fluoride. Lithium cobalt oxide (cathode) Graphite (anode) Copper Aluminum Annex I: Y32, Y42, Y45 Annex III: not available information	Temperatures above 70ºC can cause spills and ruptures of the cells or batteries. Do not incinerate or subject cells and batteries to temperatures above 70ºC. They can result in loss of seal, rupture and/or explosion of cells.	UN 3480 or UN3481 if contained or packed with equipment. UN risk code: 9	**?**
LI-ION ($LiCoO_2$) LI-POLYMER ($LiCoO_2$) Rechargeable	$LiCoO_2$ (Lithium cobaltite<2g) Carbon $LiPF_6$ Organic solvents (EC, DMC, DEC) Annex I: Y32, Y42 Annex III: H8, H3 (?), H4.1	Store in a cool preferably below 0°C) and ventilated area. Lithium-ion batteries should have their terminals insulated and be preferably wrapped in plastic bags prior to disposal.	Not informed.	?
Li-ion ($LiFePO_4$) Not available information on rechargeability. (Industrial use)	Phosphoric acid,iron(2+) Lithium salt(1:1:1) Graphite (C) Copper (Cu) Polyethylene (C2H4)n) Stainless steel Polypropylene PVC (Chloroethylene, polymer) Tin (Sn) Phosphate(1-), Hexafluoro-lithium (LiPF6) Propylene carbonate Dimethyl carbonate Annex I: Y32, Y34, Y45 Annex III: H3, H4.1, H8, H11, H12, H13	If leaked, do not allow contact with strong oxidizers, mineral acids, strong alkalis, halogenated hydrocarbons. Do not throw out a used battery or cell in the landfill. Carcinogenicity – Risk of exposure occurs only if the battery enclosure is compromised. Reproductive toxicity – Risk of exposure occurs only if the battery enclosure is compromised.	UN3480 or UN3481 Risk class 9	yes
Lithium Thionyl Chloride Battery (Li-SOCl2, Non-Rechargeable, 3.6V)	Lithium Metal, Thionyl Chloride, Aluminum Chloride, Lithium Chloride, Carbon	Firefighting: Lith-X (Class D extinguishing media) and Dried Sand are effective extinguishing media on fires involving a few lithium batteries. If cells are already catching a fire, do not use Water, CO2,	UN3090 and UN3091. Depending on their lithium metal contents, some cells or batteries may be regarded as non-	?

Generic name and information (when available)	Possible constituents and, when informed, Hazard characteristics Potential categorization Annex I (if identified) Annex II (just those identified, may have any other)	Complementary information of interest (not exhaustive). Extracted from available SDS * Regarding D10 and D5, we consider important to the SIWG to validate if feasible.	Transport regulation (extracted from available SDS)	Are there technologies for material recovery? (Yes/No)
Single Cells or Multi Packs	Annex I: to identify chemical family. Annex III: H4.3, H6.1, H8 Reacts violently with water. Reacts violently with water liberating extremely flammable gases	Halon and Dry Powder or Soda Ash Extinguishers. Put the leaked batteries into small container or plastic bag adding the neutralizing agents of Sodium carbonate (Na2CO3), chalk (CaCO3) or lime (CaO) powder. Do not short circuit, recharge, puncture, incinerate, crush, immerse, force discharge or expose to temperatures above the declared operating temperature range of the product. Risk of fire or explosion.	dangerous goods without Class 9 nomination.	
Lithium Manganese Dioxide Battery – ($LiMnO_2$) Non rechargeable - Cylindrical	Carbon Black, 1,2-Dimethoxyethane , 1,3-Dioxolane, Graphite, Lithium or Lithium Alloy, Lithium Trifluoromethanesulfonate, Lithium Trifluoromethanesulfonimide, Manganese Dioxide, Propylene Carbonate, Non-Hazardous Components: Steel, Plastic and Other Annex I: Y32, Y42 (?) Annex II: H13	In case of fire where lithium batteries are present, flood area with water or smother with a Class D fire extinguishant appropriate for lithium metal, such as Lith-X. Burning lithium manganese dioxide batteries produce toxic and corrosive lithium hydroxide fumes. Partially discharged damaged batteries can overheat and cause fires in the presence of other combustible materials.	Not informed	?
Nickel Metal Hydride Battery NiMH (or “Alkaline Manganese Dioxide-Zinc”) Cylindric or prism	Aluminum Cobalt Lithium Hydroxide Manganese Mischmetal (including: Lanthanum , Cerium, Neodymium, Praseodymium) Nickel Potassium Hydroxide Sodium Hydroxide Zinc Non-Hazardous Components Steel (iron Water, Paper, Plastic and Other) Annex I: Y23, Y35, Annex III: Cobalt (H11?), H8, H12(?), H13	In case of fire where nickel metal hydride batteries are present, apply a smothering agent such as METL-X, sand, dry ground dolomite, or soda ash, or flood the area with water. Partially discharged damaged batteries can overheat and cause fires in the presence of other combustible materials. Appropriate disposal technologies include incineration and landfilling.	Some trademarks of nickel metal hydride batteries (sometimes referred to as “Dry cell” batteries) may not be defined as dangerous goods. Nickel metal hydride batteries are defined as dangerous goods under the IMDG code (UN3496). For air and ground transportation, these batteries may not be subject to the dangerous goods regulations as they are compliant with the requirements contained in special provisions.	Yes
Silver Oxide Battery –	Graphite, Manganese Dioxide,	Partially discharged damaged batteries can overheat and	Silver oxide batteries may not be subject to	?

Generic name and information (when available)	Possible constituents and, when informed, Hazard characteristics Potential categorization Annex I (if identified) Annex II (just those identified, may have any other)	Complementary information of interest (not exhaustive). Extracted from available SDS * Regarding D10 and D5, we consider important to the SIWG to validate if feasible.	Transport regulation (extracted from available SDS)	Are there technologies for material recovery? (Yes/No)
no rechargeable Bottom shape.	Potassium Hydroxide, Silver Oxide, Sodium Hydroxide, Zinc Non-Hazardous Components (Steel, Water, Paper, Plastic and Other) Annex I: Y23, Y35 Annex III: H5.1, H8, H11 Ecological information not available. *This battery used to contain an amalgam of zinc/Hg.	cause fires in the presence of other combustible materials. Appropriate disposal technologies include incineration and landfilling.	the dangerous goods regulations provided they meet the requirements contained in the special provisions.	
Alkaline Zinc-Air Battery Non rechargeable	Zinc, (ZnO as Smoke), Steel, SS Nickel Plated, SS Copper Plating, Carbon Black, Solution of potassium hydroxide, lead, water, paper, plastic and others. Annex I: Y23, Y35, Y31(?) Annex II: not available information.	Disposal technologies include incineration and landfill.	These batteries may not be subject to dangerous goods regulations as long as they meet the requirements contained in the special provisions.	?
Alkaline Manganese Dioxide/Zinc Battery Non rechargeable Cylindric/prism	Graphite, Manganese Dioxide, Potassium Hydroxide, Zinc, Non-Hazardous Components (Steel, Water, Paper, Plastic and Other) Annex I: Y23, Y35 Annex III: H8, H13 * This battery used to contain Pb and Hg.	Disposal technologies include incineration and landfilling.	These batteries may not be subject to the dangerous goods regulations provided they meet the requirements contained in the special provisions.	?
BATERÍAS DE Ni-Cd	Nickel, Cadmium, Iron, Stainless steel. (Fe, Ni, Cr), Potassium Hydroxide (KOH) Annex I: Y26, Y35 Annex III: H8		UN 2795	?
Compact Nickel/Cadmium cells and Batteries and modules or battery systems	Active Nickel (present as Ni and Ni(OH)2), Active Cadmium (present as Cd and Cd(OH)2), Active Cobalt (present as Co(OH)2), Alkaline electrolyte	Mixing with water, acid or incompatible material may cause splattering and release of heat. Do not store in aluminum or use aluminum fittings or transfer lines as	UN2795	yes

Generic name and information (when available)	**Possible constituents and, when informed, Hazard characteristics Potential categorization Annex I (if identified) Annex II (just those identified, may have any other)**	**Complementary information of interest (not exhaustive). Extracted from available SDS * Regarding D10 and D5, we consider important to the SIWG to validate if feasible.**	**Transport regulation (extracted from available SDS)**	**Are there technologies for material recovery? (Yes/No)**
composed of these cells.	(Potassium hydroxide), Plastics, Steel, Copper Annex I: Y26, Y35 Annex III: H8, H6.1, H11, H12	flammable hydrogen may be generated. Never incinerate Ni-Cd cells Never dispose of Ni-Cd cells in landfills.		
Carbon Zinc & Zinc Chloride	Zinc Chloride (ZnCl2) Ammonium Chloride (NH4Cl) Manganese Dioxide (MnO2) Zinc (Zn) Acetylene Black Annex I: Y23, Annex III: not available information * This battery used to contain Hg, Cd and/or Pb.	The cells and batteries shall not be stored in high temperature ,the maximum temperature allowed is 60°C for a short period during the shipment , Otherwise the cells maybe leakage.	These batteries may not be subject to the dangerous goods regulations provided they meet the requirements contained in the special provisions	?
Zinc-Chloride Batteries	manganese dioxide Zinc ammonium chloride Carbon (c) Graphite zinc chloride Carbon black Annex I: Y23 Annex III: H6.1, H8, H11, H12			?