Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

Guidance on the Safe Storage of Lithium-Ion Batteries at Waste Handling Facilities

THE CIRCULAR ECONOMY PROGRAMME
The Driving Force for Ireland's Move to a Circular Economy

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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Acknowledgements

This guidance document was prepared with the assistance of Sweco Ireland Ltd.

ISBN 978-1-80009-149-8

Contents

Glossary of terms

ADR	Agreement Concerning the International Carriage of Dangerous Goods by Road
Anode	Negative battery electrode that releases electrons
APP	Accident Prevention Procedure(s)
ATF	Authorised treatment facility
CA site	Civic amenity site
Cathode	Positive battery electrode that acquires electrons
CoR	Certificate of Registration
DGSA	Dangerous Goods Safety Advisor
DHLGH	Department of Housing, Local Government and Heritage
EC	European Commission
EEE	Electric and Electronic Equipment
EHS	Environmental, Health and Safety
EV	Electric vehicle
ELV	End-of-Life vehicle
ELVES	A producer responsibility organisation (see **www.elves.ie**)
EMS	Environmental Management System
EPA	Environmental Protection Agency
ERP	Emergency Response Procedure(s)
ERP Ireland	A producer responsibility organisation (see **www.erp-recycling.org/ie**)
EU	European Union
EuRIC	The European Association for Recycling
FRA	Fire risk assessment
GPS	Global Positioning System
HP	Hazard property
HSA	Health and Safety Authority
IATA-DGR	International Air Transport Association – Dangerous Goods Regulation
IE licence	Industrial Emissions licence
IMDG Code	International Maritime Dangerous Goods Code
IMO	International Maritime Organisation
Li-Ion	Lithium-ion
LoW	List of waste
NHWMP	National Hazardous Waste Management Plan
NWCPO	National Waste Collection Permit Office
PAH	Polycyclic aromatic hydrocarbon
PBB	Polybrominated biphenyl
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
POP	Persistent organic pollutant

PRI	Producer responsibility initiative
PRO	Producer responsibility organisation - a legal entity that financially or financially and operationally organises the fulfilment of extended procedure responsibility obligations on behalf of several producers
RID	The Regulation concerning the International Carriage of Dangerous Goods by Rail
TFS	Transfrontier shipment
WEEE	Waste Electrical and Electronic Equipment
WEEE Ireland	A producer responsibility organisation (see **www.weeeireland.ie**)
WCP	Waste Collection Permit
WFD	Waste Framework Directive
WFP	Waste Facility Permit

1. Introduction

1.1 Background

With the increased use of Lithium-ion (Li-ion) batteries in consumer electronic equipment and electric vehicles (EVs) over recent years, there has been an associated increase in the generation of Li-ion battery waste. When used in accordance with manufacturer's instructions, Li-ion batteries are safe in the wide range of applications in which they are intended for use. However, if batteries become damaged or begin to fail, there is a significant risk of fire and release of hazardous substances. See Section 3.3.3 for images of damaged Li-ion batteries.

This risk increases when the Li-ion batteries enter the waste stream, as the possibility of damage increases due to crushing, impact or poor handling. However, when disposed of through the appropriate battery recycling channels, using appropriate containers and authorised waste handling facilities, the risk is reduced.

Despite this, Li-ion waste batteries still arise in the general waste stream and studies have shown that numerous fire incidents have been reported during transport and at waste treatment and recycling facilities in Ireland and abroad[1].

The National Hazardous Waste Management Plan 2021-2027 (NHWMP) acknowledges the continuing growth in Ireland in the use of batteries generally, the corresponding growth in this waste stream and the need for guidelines on the safe storage of Li-ion batteries at waste handling facilities.

1 Ollion, L., Anta, M., Herreras, L., Characterisation of fires caused by batteries in WEEE Survey results from the WEEE management chain (2020) – Part A, a WEEE Forum and EuRIC report.

NHWMP 2021-2027 Recommendation 14

"Promote best practice in the management of commercial hazardous waste streams."

Key Action 14.2:
Prepare and publish guidelines for the safe storage of Lithium-ion batteries at waste handling facilities.

This guidance note has been prepared in response to Key Action 14.2 of the NHWMP.

1.1.1 Current Battery Recycling Channels in Ireland

Battery producers in Ireland have obligations (collection and recycling and reporting) under the European Union (Batteries and Accumulators) Regulations 2014, as amended. The producer can fulfil some of these obligations through membership of an approved compliance scheme operated by a Producer Responsibility Organisation or 'PRO' (e.g. WEEE Ireland, ERP Ireland), which funds the collection and recycling of batteries. Since 2008, these schemes (which are free of charge) have established a well-managed collection network across retailers, Civic Amenity (CA) sites and industry. The current battery recycling channels in Ireland are summarised in Figure 1.

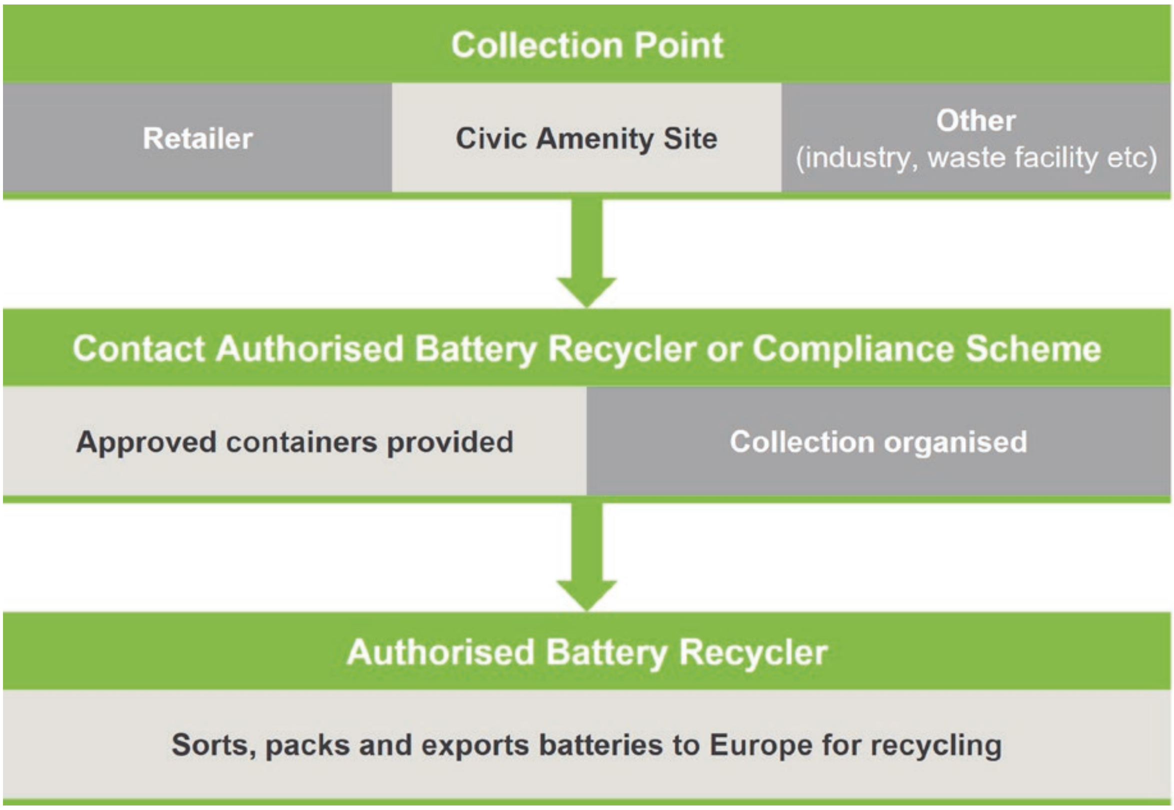

Figure 1: Battery recycling channels in Ireland

Some specialist or industrial Li-ion batteries may lie outside of the main schemes for waste batteries. This includes electric vehicle (EV) batteries. The recycling of waste EV batteries is managed through a separate compliance scheme, ELVES.

ELVES – Programme for Electric Vehicle Batteries

ELVES is the compliance scheme for End-of-Life Vehicles (ELVs) in Ireland. ELVES is a non-profit company set up by vehicle manufacturers to help deliver on their obligations under the European Union (End-of-Life Vehicles) (Amendment) Regulations 2016 (S.I. No. 566 of 2016). Since 2018, ELVES has operated the Electric ELVES programme to support authorised treatment facilities (ATFs) in their handling and recycling of electric and hybrid vehicles. The Electric ELVES programme provides ATFs with the following support:

- Dismantling information provision;
- Training;
- Free collection and recycling of the battery;
- Additional support in the event that the vehicle/battery is potentially damaged.

Further information on the recycling of ELVs and the Electric ELVES programme is available on the ELVES website (**www.elves.ie**).

1.2 Scope

This guidance document is limited to the handling and storage of secondary or rechargeable waste Li-ion batteries (e.g. mobile phone batteries, power tool batteries, etc.) at waste handling facilities. Primary lithium batteries, which are mostly non-rechargeable e.g. watches, single use vaping devices, etc. are excluded from the guidance as they do not pose the same safety or fire risk. Examples of Li-ion battery applications are listed in Section 1.3.

This guidance document is limited to the handling and storage of waste Li-ion (secondary cell) batteries at:

- Retail collection points (distributors);
- CA Sites – private or public site providing members of the public with recycling and disposal options for a wide range of materials including non-hazardous and hazardous household wastes;
- Waste management facilities carrying out a waste disposal or recovery activities and holding a Certificate of Registration (CoR), Waste Facility Permit (WFP), Waste licence or Industrial Emissions (IE) licence.

All of the above facilities are referred to collectively throughout this document as waste handling facilities for the purpose of this guidance note.

It is the responsibility of each waste management facility operator to ensure that they comply with all relevant legislation in relation to safety, including fire safety. Nothing in this guidance should be construed as negating the operator's statutory obligations or requirements under any other enactments, regulations or conditions of a Certificate of Registration (CoR), Waste Facility Permit (WFP), Waste licence or Industrial Emissions (IE) licence.

1.2.1 Li-ion Batteries and WEEE

Li-ion batteries may arise within waste electrical and electronic equipment (WEEE), however, this guidance is focused on the safe storage of Li-ion batteries at waste handling facilities and is not intended to address the wider measures required for the safe management of WEEE.

A range of guidance documents related to WEEE and batteries are available on the EPA website[2]. The website of WEEE Ireland also provides further information on the safety concerns associated with WEEE and recommended precautions[3].

1.2.2 Public awareness

Notwithstanding the safety measures employed at waste handling facilities, it is recognised that a significant challenge remains for all facilities in the handling of waste Li-ion batteries which are incorrectly disposed upstream of the collection point or waste facility.

The mywaste.ie[4] website provides information to the general public on what to do with WEEE, including information on what happens to waste batteries, how waste batteries are processed and how to recycle.

Vaping devices and e-cigarettes are sold using both primary lithium batteries (non-rechargeable) and secondary Li-ion batteries (rechargeable). Anecdotal reports suggest disposable vapes have emerged as a new litter item with concentrations found close to schools and music events. However, as disposable vapes contain primary cell lithium batteries, they are outside the scope of this guidance. Guidance for the recycling of vape and e-cigarette WEEE is available on the WEEE Ireland website[5].

2 https://www.epa.ie/our-services/compliance--enforcement/waste/weee/guidance-on-weee-and-batteries/

3 https://www.weeeireland.ie/health-safety/categories-of-waste/weee/

4 https://www.mywaste.ie/what-to-do-with-my-waste-electrical-and-electronic-equipment-weee/

5 https://www.weeeireland.ie/vape-e-cigarette-device-recycling/

1.3 Examples of Li-ion battery applications

A non-exhaustive list of common applications for Li-ion batteries is included in Table 1.

Table 1: Example of Li-ion battery applications

Application	Device
Consumer device batteries	▪ Mobile phones ▪ Smartphones ▪ Laptops, tables, electronic notebooks, e-readers ▪ Smart speakers ▪ Digital cameras, camcorder ▪ Portable gaming consoles ▪ Electronic toys ▪ Wearable devices e.g., smart watches, fitness trackers, and other wearables/GPS devices ▪ Electric toothbrushes ▪ Medical devices e.g., portable oxygen concentrators, insulin pumps, etc. ▪ Drones ▪ E-cigarettes, vaping devices (rechargeable)
Power tool batteries	▪ Cordless drills, saws and other power tools ▪ Cordless vacuum cleaners ▪ Gardening tools
E-mobility batteries	▪ Electric vehicles ▪ E-bikes ▪ Scooters
Energy storage	▪ Batteries used for storage of energy generated by solar panels for later use ▪ Batteries used for emergency backup power

Figures 2-9 show a range of different Li-ion batteries.

Figure 2: Example of EV batteries

Figure 3: Example of mobile phone and smart phone batteries

Figure 4: Example of Li-ion battery pack and charging unit e.g., cameras

Figure 5: Example of small appliance Li-ion batteries e.g., power tools, cameras, etc.[6]

Figure 6: Example of rechargeable device batteries e.g., laptops, tablets, etc.[7]

6 Lithium Battery Guidance Document. Transport of Lithium Metal and Lithium-Ion Batteries. IATA (2020)

7 Sorting and Packaging Instructions for Lithium Rechargeable and Lithium Primary Batteries, Accurec (2021)

Figure 7: Example of power tool batteries e.g., cordless drill, vacuum cleaner, etc.

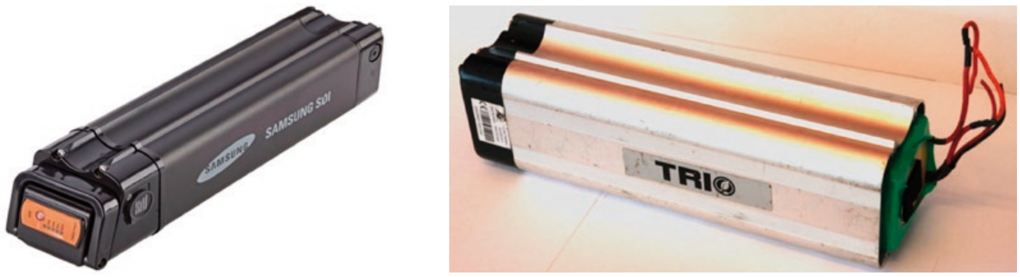

Figure 8: Example of e-mobility batteries e.g., e-bike, scooter, etc.


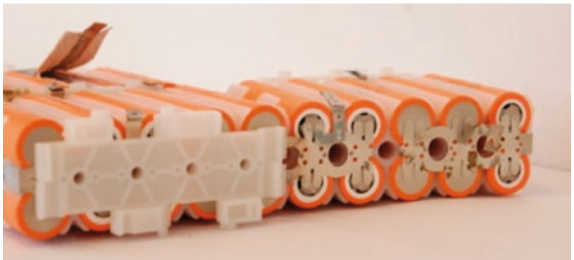

Figure 9: Example of other Li-ion batteries e.g., robotic devices, etc.

1.4 Legislation

The legislative framework for the management of waste Li-ion batteries is set out in Appendix A.

2.0 Waste Li-ion Batteries

2.1 When is a Li-ion battery a waste?

Waste is defined by the Waste Framework Directive (WFD) and in turn within the Waste Management Act 1996, as amended, to mean:

"Any substance or object which the holder discards or intends or is required to discard"

A battery can therefore become a waste whenever it is discarded by the holder, regardless of its state of charge, age or physical condition.

The WFD defines 'hazardous waste' as "*waste which displays one or more of the hazardous properties listed in Annex III*" to the WFD (of which there are fifteen, HP 1 to HP 15 e.g., HP 1 Explosive, HP 2 Oxidising, HP 3 Flammable, etc.). The definition for hazardous waste has been transposed in Ireland by way of the Waste Management Act 1996, as amended (which includes the Annex III properties within the Second Schedule to the Act).

2.2 Waste classification

Waste classification has been harmonised across the EU by way of the European 'List of Waste' (LoW)[8], which provides a singular (though non-exhaustive) list for coding of waste.

2.2.1 List of Waste (LoW) and waste batteries

The LoW and system of waste classification is detailed in the EPA publication "*Waste Classification, List of Waste and Determining if Waste is Hazardous or Non-Hazardous*"[9].

While there is no specific LoW for Li-ion battery waste, a number of LoW codes may be applicable as highlighted in Table 2. These are for reference purposes only. Given the broad variety in both the design and applications of Li-ion batteries, waste classification must be carried out on a case-by-case basis with reference to the aforementioned legislation and EPA guidance for waste classification.

8 Commission Decision 2000/532/EC of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste [commonly referred to as 'The List of Waste (LoW)'].

9 Available for download at https://www.epa.ie/publications/monitoring--assessment/waste/waste-classification.php

Table 2: Li-Ion Waste Batteries – Common LoW Codes

LoW Code	Waste Description
09 01	**Wastes from the photographic industry**
09 01 11*	single-use cameras containing batteries included in 16 06 01 (lead batteries), 16 06 02 (Ni-Cd batteries) or 16 06 03 (mercury-containing batteries)
09 01 12	single-use cameras containing batteries other than those mentioned in 09 01 11
20 01	**Municipal wastes – separately collected fractions (except 15 01)**
20 01 33*	batteries and accumulators included in 16 06 01(lead batteries), 16 06 02 (Ni-Cd batteries) or 16 06 03 (mercury-containing batteries) and unsorted batteries and accumulators containing these batteries
20 01 34	batteries and accumulators other than those mentioned in 20 01 33
20 01 35*	discarded electrical and electronic equipment other than those mentioned in 20 01 21 (fluorescent tubes and other mercury-containing waste) and 20 01 23 (discarded equipment containing chlorofluorocarbons) containing hazardous components Note A
20 01 36	discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35
16	**Wastes not otherwise specified in the list**
16 02	**Wastes from electrical and electronic equipment**
16 02 13*	discarded equipment containing hazardous components Note A other than those mentioned in 16 02 09 to 16 02 12
16 02 14	discarded equipment other than those mentioned in 16 02 09 to 16 02 13
16 06	**Batteries and accumulators**
16 06 05	other batteries and accumulators
16 06 06*	separately collected electrolyte from batteries and accumulators

Note A = hazardous components from electrical and electronic equipment may include accumulators and batteries mentioned in 16 06 marked as hazardous: mercury switches, glass from cathode ray rubes and other activated glass, etc.

2.2.2 Future changes

It is noted that recital 116 of the Batteries Regulation 2023/1542 states that the Commission Decision 2000/532/EC, establishing the LoW, should be revised to reflect all battery chemistries, in particular the codes for lithium-based waste batteries, in order to enable proper sorting and reporting of such waste batteries. As such, further changes to the LoW relevant to waste batteries can be expected in the future.

Further information on the legislative framework for waste and waste batteries is provided in Appendix A.

2.3 Hazards

Li-ion batteries are designed to withstand the stresses associated with normal use. When handled in accordance with manufacturer recommendations and guidelines, the risk of an incident is generally low.

However, due to their high energy density and the risk of ignition, significant safety and environmental hazards arise when Li-ion batteries are mishandled or stored in unsuitable conditions.

Given the risk of physical damage to waste Li-ion batteries when being loaded/unloaded, sorted or processed using mechanical equipment (e.g., shredding), waste management activities pose a high risk of battery failure, potentially resulting in a thermal event (e.g., spark, fire, explosion, etc.).

The potential hazards and associated consequences with the storage of waste Li-ion batteries in waste handling facilities are summarised in Table 3 and Figure 10.

Table 3: Overview of Safety Hazards – Waste Li-ion Batteries

Hazard	Potential Consequences
Short circuit	Overheating Venting Thermal runaway Fire
Physical damage (e.g., denting, puncture, rupture, impact)/shock	Release of potentially hazardous materials Spontaneous ignition Short circuit
Thermal abuse/external heating (excessive heat)	Venting Explosion
Water ingress/moisture	Corrosion Release of potentially hazardous materials Short circuit
Long-term storage/decomposition	Venting Short circuit
Residual current – high voltage batteries	Electric shock

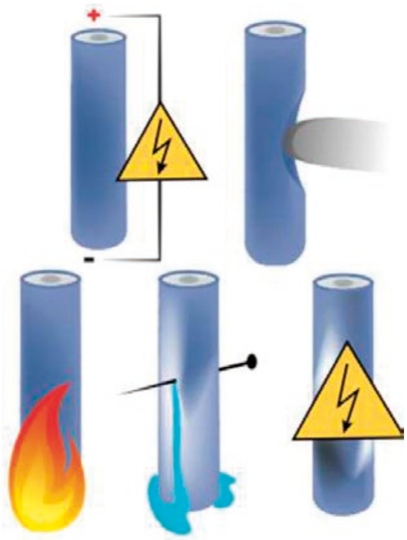

Figure 10: Safety Hazards – Waste Li-ion Batteries[10]

The main safety and environmental hazards are described further in Sections 2.3.1 and 2.3.2. **The potential consequences are further detailed in Appendix B.**

2.3.1 Safety hazards

Short circuit

Short-circuiting is a process involving the uncontrolled discharge of the battery's stored energy, posing the risk of a thermal event e.g., spark, fire, explosion, etc.

The risk of a thermal event occurring increases when waste batteries are disturbed or moved. For example, a container of waste batteries may remain safe while undisturbed, but movement or shock/impact (e.g., during transit) may cause a short circuit to take place. Furthermore, the potential dangers can take some time to become apparent. For example, in a damaged battery, the heat from a short circuit can build up slowly over time with potential for a fire to occur several hours after the initiating event.

Li-ion batteries (or the consumer electronics that house them) are generally equipped with protective circuitry to regulate charge and protect against external short-circuiting. However, damage or external stress to waste batteries may compromise the protective circuitry, thereby increasing the risk of a short circuit.

If a battery is subject to rapid exposure to a warm and moist environment from a cold environment, the temperature change can lead to condensation forming within the battery casing, also posing a risk of internal short-circuiting.

Physical damage and shock

Physical impact or shock to WEEE or waste Li-ion batteries may lead to a short circuit. Such an impact (e.g., by crushing, dropping, etc.) may directly damage and compromise a waste battery (risk of internal short circuit as above). The movement of waste materials may also cause a conducting material to connect battery terminals (risk of external short circuit as described above).

In addition to the risk of short circuit, ruptured or damaged batteries can also leak electrolyte, which is a hazardous substance.

Thermal abuse/external heating

Li-ion batteries contain safety mechanisms designed to provide protection against overheating. However, even with these safety features, thermal events can still occur.

If overheated, Li-ion batteries may suffer thermal runaway and cell rupture. Thermal runaway occurs where an increase in temperature changes the conditions in a way that causes a further increase in temperature. In extreme cases, this can lead to leakage of the battery contents, explosion or fire.

10 Image source: Herreras-Martínez, L., Anta, M., Bountis, R. (2021) et al. Recommendations for tackling fires caused by lithium batteries in WEEE- A report of the Batteries Roundtable.

Water ingress/moisture

In the presence of moisture, the lithium contained in Li-ion batteries reacts with water to form lithium hydroxide (LiOH), a caustic liquid susceptible to leakage in the event of a Li-ion battery explosion. The reaction of lithium and water also generates hydrogen gas, presenting a risk of fire and explosion.

It is noted that the concentration of lithium in batteries is relatively small and the main concern with water entering a battery is the risk of short-circuiting and subsequent thermal runaway as described previously.

Long term storage/decomposition

Li-ion cells or battery modules can be compromised as a result of battery aging i.e., when vulnerable materials inside the battery deteriorate. This includes dendrite formation, which refers to the growth of conductive crystals inside a Li-ion battery. Crystals formed inside a battery may result in a short circuit.

Residual current – high voltage batteries

Exposed battery terminals can pose an electrical shock hazard or spark, even on disconnected batteries. Some battery systems can discharge residual energy at high rates of current. Shorting of the terminals or cables (i.e., using too small of a load) can result in severe electrical arcing[11].

2.3.2 Environmental hazards

Waste Li-ion batteries contain a variety of chemicals including reactive salts, volatile organic electrolytes and additives. A key environmental concern is the potential for release of heavy metals (e.g., cobalt, copper and nickel) used in the manufacture of Li-ion batteries when batteries are damaged or compromised.

Research by the UK Royal Society of Chemistry (UK RSC)[12] identified the possible routes of emission and pollutants released from waste Li-ion batteries, as shown in Table 4. This research also noted that chemical additives used in Li-ion batteries are often commercial secrets and hence their toxicity (and combustion products in the event of fire) are largely unknown.

11 Arcing is a type of electrical discharge that occurs when electrons flow between two conductors, usually metal, in an environment with a gas or vacuum. Conductors can be wires, rods or other objects that are capable of carrying an electrical current. When the electrical potential difference between the two conductors is high enough, the electrons will flow form one conductor to the other, causing a spark or arc.

12 Energy Environ. Sci., 2021, 14, 6099

Table 4: Possible pollutants and routes of their emission released from Li-ion batteries[13]

Battery Component	Source of Pollutant	Specific Pollutant	Route	Affected Environment	Hazard
Pack casing	Steel	i.e., Fe, Al, Ni, Cr other	Leaching	Land Natural waters	In excess toxic to wildlife Accumulation in plants and crops
Module casing	Steel Aluminium	Fe, Ni, Cr other Al	Leaching	Land Natural waters	In excess toxic to wildlife Accumulation in plants and crops
Cell packing	Aluminium foil Polymers Ni-Coated steel	Al, Ni PET, PP	Leaching Fire	Natural waters Land Air	In excess toxic to wildlife Accumulation in plants and crops
Cathode	Metal Metal oxides	Al LMO – Li/Mn/O LFP – Li/Fe/P/O NMC – Li/Ni/Mn/Co/O LCO – Li/Co/O NCA – Li/Ni/Co/Al/O	Leaching Dust	Land Natural waters Air	Toxic to the various organism Toxic to humans if inhaled In excess toxic to wildlife Accumulation in plants and crops
Anode	Copper Graphite	Cu C (nanomaterial) LTO – Li/Ti/O	Leaching	Land Natural waters	In excess toxic to wildlife Accumulation in plants and crops Toxic to humans if inhaled

13 Energy Environ. Sci., 2021, 14, 6099. Environmental impacts, pollution sources and pathways of spent lithium-ion batteries

Battery Component	Source of Pollutant	Specific Pollutant	Route	Affected Environment	Hazard
Separator	Polymers	Polyethylene (PE) Polypropylene (PP)	Leaching Fire Dust	Land Natural waters Air	Microplastics accumulation
Binder	Polyvinylidene fluoride (PDV)	Hydrofluoric acid (HF)	Fire	Air	Toxic to humans if inhaled Toxic to humans if in contact
Electrolyte	Ethylene carbonate Propylene carbonate Dimethyl carbonate Diethyl carbonate Salts: $LiPF_6$ Additives	HF SO_x HCN H_2 CO CO_2 NO_x COS HCl Degradation products of electrolyte (i.e., C_2H_4, CH_3COCHO, etc.) Ionic liquids Unknown additives/ degradation products	Fire Vapours/gases Leaching	Air Land Natural waters	Toxic to humans if inhaled Toxic to humans if in contact Toxic to wildlife Accumulation in soils

The possible emission routes of pollutants from Li-ion battery waste into the environment are also summarised in Figure 11.

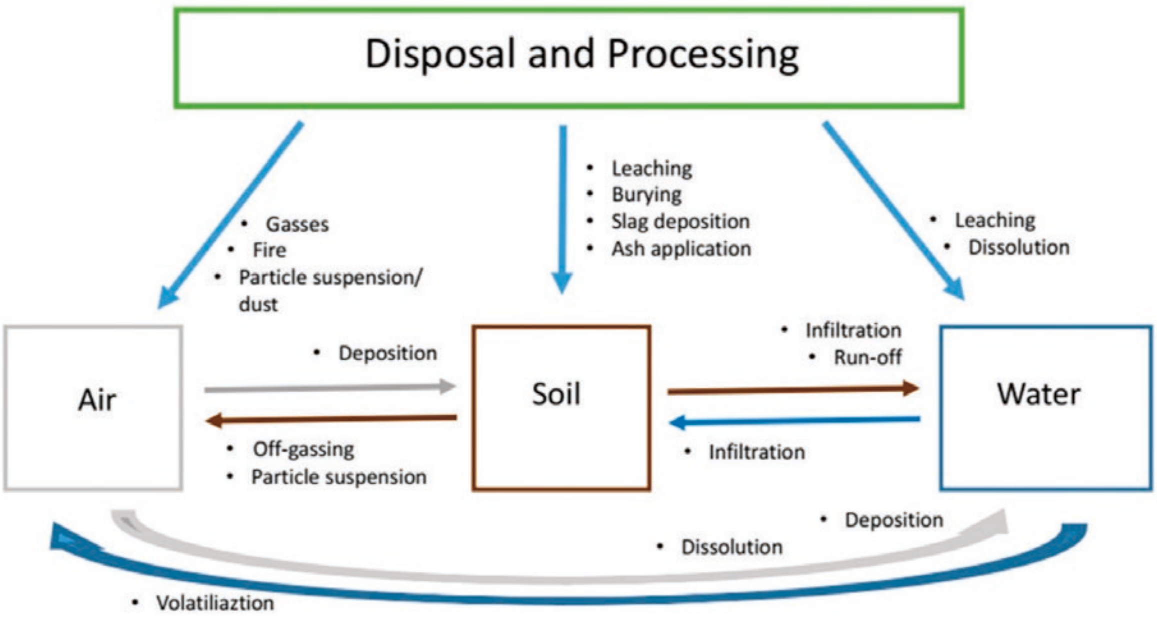

Figure 11: Li-ion Battery Waste – Potential Emission Routes[14]

Run-off to waterbodies can occur as a result of contaminated rainwater or wash water runoff, spillages/ leaks or contaminated firewater. Analysis of the composition of by-products of a Li-ion battery fire, found that in addition to heavy metals, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) – which are irritants and persistent organic pollutants (POPs) – were also detected[15].

14 Energy Environ. Sci., 2021, 14, 6099

15 M. Held et al. Thermal runaway and fire of electric vehicle lithium-ion battery and contamination of infrastructure facility Renew. Sustain. Energy Rev. (2022) – https://doi.org/10.1016/j.rser.2022.112474

3.0 Storage Guidelines for Waste Li-ion Batteries

3.1 Retail collection (distributors)

The obligations of a retailer (also termed 'distributor' for the purposes of the WEEE Directive and WEEE Regulations) for the 'take back' of both WEEE and batteries are detailed in separate EPA guidance "*Waste Electrical and Electronic Equipment (WEEE) and Batteries Regulations Guidance for Retailers and Distributors*"[16].

Retailers can obtain free plastic boxes or drums for collection of waste portable batteries from WEEE Ireland or ERP Ireland. WEEE Ireland and ERP Ireland will also organise collection of boxes/drum once they are full. Alternatively, retailers can bring waste portable batteries that have been collected through take back, to the local CA site.

The following best practice measures are recommended for distributors:

- All waste receptacles and containers for waste batteries should be held in an area that is:
  - Cool and dry – located away from sources of heat and moisture;
  - Out of direct sunlight, covered and weatherproof;
  - Segregated from other combustible materials;
  - Out of the reach of children;
  - Outside of building access/escape routes;
  - Subject to routine inspection or supervision.
- Leaking batteries should not be accepted or deposited with other batteries – distributors are reminded that there is no obligation to accept a leaking battery;
- A routine collection frequency for waste batteries should be agreed and maintained with WEEE Ireland/ERP Ireland;
- Where lithium-type batteries are stored together, it is best practice that the terminals of these batteries be taped (as shown in Figure 12) to avoid short circuit and/or fie (batteries should not be wrapped in conductive materials like aluminium foil).

Figure 12: Waste lithium batteries with taped terminals[17]

3.2 Civic amenity sites

The following best practice measures are recommended for CA sites collecting waste Li-ion batteries and mixed waste loads:

- Risk assessment – the potential for receipt of waste Li-ion batteries and appropriate control measures should be considered as part of the site or facility risk assessment;

16 Guidance for Retailers and Distributors of Electrical and Electronic Equipment (EEE) and Batteries. EPA, 2023 (https://www.epa.ie/publications/compliance--enforcement/waste/guidance-for-retailers-and-distributors-of-eee-and-batteries.php)

17 WEEE Ireland Battery Presentation Guide, WEEE Ireland/KMK Recycling

- Provision of adequate signage, labelling and communication to inform waste holders of the requirement to segregate and safely deposit waste batteries and WEEE in the designated area(s);
  - Maintain a supply of tape (non-metallic) to facilitate taping of battery terminals and/or exposed battery wires;
- Site waste reception/acceptance, handling, inspection and quarantine procedures to address risk of receiving waste Li-ion batteries and site-specific control measures;
- Provision of designated storage locations for both intact and damaged batteries;
  - Damaged or leaking batteries should be segregated and treated as 'hazardous' waste under LoW code 16 06 06 (see Section 2.2 on waste classification);
- Waste disposal by members of the public should be organised or supervised in such a manner that reduces the deposit of high-risk waste items, such as waste batteries, in the wrong receptacle;
  - Awareness for those discarding waste can be increased with high quality and clear signage to indicate the correct means of disposal for battery waste;
  - Co-locating small WEEE (including IT) and battery containers so it is easier for the public to recycle their batteries at the same time as dealing with their WEEE;
  - Positioning the small WEEE (including IT) and battery containers to a more central location where operators may better intercept and monitor compliance of users.

Those CA sites which are engaged in additional pre-treatment or other waste treatment activities should also note the recommended practices for waste treatment facilities, included in Section 3.3.

3.3 Waste treatment facilities

Given the greater risk of damage to a waste Li-ion battery during transit/handling at a waste treatment facility, as well as the greater potential for an unidentified waste battery to arise in mixed waste, additional measures are required to ensure the safe management of waste Li-ion batteries in such facilities. This includes waste management facilities engaged in pre-treatment activities such as sorting, shredding, packaging, compacting, etc.

3.3.1 Management systems and risk assessment

Waste management facilities holding a CoR, WFP, Waste Licence or IE licence will typically be obliged to operate in accordance with an Environmental Management System (EMS) or waste management procedures as specified by the conditions of the CoR/WFP/licence.

Related EPA guidance and requirements for the operation of non-hazardous waste facilities are set out in the following documents:

- Guidance Note: Fire Safety at Non-Hazardous Waste Transfer Stations (2013)[18];
- Guidance on Fire Risk Assessment for Non-Hazardous Waste Facilities (2016)[19].

The EPA has also prepared guidance on the minimum Agency requirements for preparing Accident Prevention Procedures (APP) and Emergency Response Procedures (ERP):

- Guidance to Licensees on the Preparation of Accident Prevention Procedures and Emergency Response Procedures (2016)[20].

18 https://www.epa.ie/publications/compliance--enforcement/waste/EPA_Fire_Safety_Guidance_Note_WEB_FINAL_2.pdf

19 https://www.epa.ie/publications/compliance--enforcement/waste/FINAL-FRA-GUIDANCE.PDF

20 https://www.epa.ie/publications/compliance--enforcement/licensees/reporting/EPA-2016-Guidance-on-APP-and-ERP.pdf

It is recommended that the EMS, written procedures, Fire Risk Assessment (FRA), APP and ERP address the risk of waste Li-ion batteries as appropriate. This recommendation extends to those facilities where waste Li-ion batteries are not routinely accepted but may be received as non-conforming waste requiring quarantine.

3.3.2 Waste acceptance and processing areas

The following measures are recommended if waste Li-ion batteries are present in waste acceptance and processing areas:

- Employees should be appropriately trained to identify, segregate and manage waste Li-ion batteries, including WEEE which may contain battery waste;
- Waste should be promptly checked for non-conforming battery/WEEE waste prior to mechanical processing i.e., before transfer to conveyor belt/picking line, shredding etc;
- Hot spots can be identified using thermographic camera, however, visual inspection for bulging, smoking or hissing batteries is often as effective for identifying batteries;
- Assess the battery for visual damage without picking it up;
- If the battery is damaged or the state of the battery is unknown, advice should be sought from site supervision/safety management team;
- Batteries that are swelling, smoking, leaking or overheating should be treated with extreme caution and in line with the emergency measure for such a scenario;
- Batteries should be removed without being touched e.g., by using a plastic (non-conducting) shovel or similar;
- Batteries should be stored safely in a designated quarantine area and packed with an absorbent, non-flammable material (e.g., sand, vermiculite);
- In emergency situations, the best course of action may involve removal of a damaged/leaking battery outdoors – clear of people, structures, vehicles and plant/equipment;
- Batteries should not be allowed to accumulate in significant quantities and should be moved to the quarantine area as soon as possible;
- Drainage from a waste unloading area should be diverted for collection and safe disposal in accordance with the conditions of the facility licence/permit/CoR.

Within mixed waste consignments, the potential remains for an unidentified waste battery to initiate a fire event many hours after the waste is first unloaded. For those facilities accepting mixed waste consignments which are not operational on a 24/7 basis, all unloaded waste should be sorted and processed to a safe point during hours of supervision.

3.3.3 Quarantine and damaged/leaking batteries

Where battery waste is received as a non-conforming waste, it must be placed in a designated waste quarantine area. Similarly, a dedicated quarantine location for damaged or leaking batteries is recommended.

The following measures are recommended for quarantine areas used for waste Li-ion batteries:

- Quarantine areas for waste Li-ion batteries may be located internal to, or external to the main building(s) of a waste management facility, but in all cases should remain:
  - Out of direct sunlight, covered (e.g., canopy if outdoors) and weatherproof;
  - Cool and dry – located away from sources of heat and moisture;
  - Located in an area that is not subject to extreme heat (>50°C) or extreme cold (<10°C);

Figure 13: Examples of damaged batteries[21]

- Segregated from other combustible materials;
- Well-ventilated with forced airflow if necessary;
- Located within a bunded area[22] or in an area with an impermeable surface and measures for the safe collection and disposal of floor drainage;
- Out of the reach of children;
- Subject to routine inspection or supervision;
- Secure and safe from vandalism.

- Lighting should be adequate to allow for clear identification of all waste;
- Damaged or leaking batteries should be isolated from other battery waste and packaged separately along with any absorbent waste which may have been used in controlling the spill;
- Appropriate signage and floor markings to indicate any specific waste storage areas and any segregation of waste required – depending on the size and layout of the waste management facility, appropriate signage may also be required to identify the different types of waste held in a particular area;
- An inert filing material (e.g. vermiculite, sand) should be placed around the damaged or leaking battery-this will reduce risk of a short circuit, will help conduct heat away and will starve any heating battery of oxygen and fuel.

3.3.4 Waste containers

The following best practice measures are noted for the storage of waste Li-ion batteries in containers:

- Where lithium-type batteries are stored together, it is advised that the terminals of these batteries be taped (see Figure 12);

21 Image source: Batteries Roundtable, INOBAT

22 IPC Guidance Note on the Storage and Transfer of Materials for Scheduled Activities, EPA, 2013

Figure 14: Example of containers used for lithium batteries including waste Li-ion batteries[23]

- Similarly, for certain batteries having exposed wire ends, it is recommended that these are secured with tape to prevent short circuiting;
- Alternatively, batteries and trailing wires can be individually wrapped and sealed in clear plastic;
- No metallic ties or foil should be used to wrap batteries;
- Batteries should be packaged in a way that ensure they will not be crushed or damaged in storage or transit;
- Storage containers should be inspected regularly to ensure that they are intact and fit for purpose;
- Containers should be kept closed and only filled to the approved capacity.

Examples of containers (or packages) used and correctly labelled for the storage of waste lithium batteries, including waste Li-ion batteries, are shown in Figure 14 (a-e) as follows:

(a) Waste Li-ion batteries packaged for recycling in a UN approved fibre box;

(b) UN approved 60 litre steel drum with lid (in this case, the batteries are filled in the drum surrounded by vermiculite and the drum is also equipped with a pressure relief device);

(c) Steel barrel equipped with a spark filter and pressure relief on the lid, specially designed for the collection, storage and transport of defective end-of-life lithium batteries (according to SV 377 ADR);

(d) WEEE Ireland 5 kg 'blue box' battery container for recycling of domestic batteries;

(e) UN approved 60 litre HDPE drum with a liner.

23 Image sources: (a) KMK Recycling (b)-(c) Batteries Roundtable (d)-(e) WEEE Ireland Battery Presentation Guide.

Figure 15 shows a sample procedure for the filling of a UN certified steel drum with an inner plastic lining. Once the inner liner is in place, the drum can be filled as shown, taking appropriate care to surround the waste Li-ion batteries with vermiculite. A top or capping layer of vermiculite is applied before the inner liner is tied and the drum is closed and secured for transport.

Figure 15: Sample procedure – filling a lined drum with waste Li-ion batteries and vermiculite packing

3.4 Transport

3.4.1 Carriage of dangerous goods

Specific regulations apply to each mode of transportation for dangerous goods i.e.:

- International Carriage of Dangerous Goods by Road (ADR) (road transport);
- International Maritime Dangerous Good Code (IMDG) (maritime transport);
- International Air Transport Association (IATA) Dangerous Goods Regulations (DGR) (air transport);
- International Carriage of Dangerous Goods by Rail (RID).

The European Communities (Carriage of Dangerous Goods by Road and Use of Transportable Pressure Equipment) Regulations 2011[24] (as amended) provide the legal basis for ADR (Transport of Dangerous Goods) in Ireland.

ADR provides for the classification of all 'dangerous goods' into one of nine main hazard classification groups. Due to the risk of short circuit and fire, Li-ion batteries are classified as dangerous goods under Class 9 (Miscellaneous dangerous items), as follows:

- UN 3480: Lithium-Ion batteries;
- UN 3481: Lithium-Ion batteries contained in equipment or packed with equipment.

The HSA has published a guide for businesses involved in the carriage of dangerous goods by road "*Carriage of Dangerous Goods by Road 2021*"[25].

24 S.I. No. 349 of 2011

25 https://www.hsa.ie/eng/publications_and_forms/publications/chemical_and_hazardous_substances/hsa_carriage_of_dangerous_goods_by_road_2021.pdf

In line with ADR requirements, the Class 9A lithium battery dangerous goods label is required to be applied on all shipments containing lithium-ion batteries (or other class 9 dangerous goods).

Further information can be found in the following ADR regulations:

- Damaged or defective batteries – ADR SV 376, P908;
- Critically defective batteries – ADR SV 376, P911;
- Batteries for disposal and recycling – ADR P909.

All participants involved in the transport of dangerous goods by road, including waste Li-ion batteries, are subject to ADR requirements, including the consignor, carrier, driver, loader, filler, packer, unloader and consignee.

All businesses that carry significant quantities of dangerous goods by road have a legal obligation to appoint a Dangerous Goods Safety Advisor (DGSA). Where the operator of a waste management facility is uncertain regarding ADR requirements relating to the consignment, carriage or related packing, loading, filling or unloading of dangerous goods, it is recommended that the advice of a qualified DGSA is obtained.

3.4.2 Waste collection and hauliers

Only those waste collectors (hauliers) with a valid Waste Collection Permit (WCP) may legally transport consignments of waste. WCPs are issued by local authorities under the Waste Management (Collection Permit) Regulations 2007[26] (as amended).

The National Waste Collection Permit Office (NWCPO – operated by Offaly County Council) has responsibility for the issuing of collection permits. WCPs include the waste categories (by LoW code) which a waste haulier is permitted to transport, as well as the list of areas in which the waste collector is allowed to operate. The national register of waste collection permits can be searched on the NWCPO website (**www.nwcpo.ie**).

26 S.I. No. 820 of 2007

4.0 Emergency Preparedness and Response

As stated previously, nothing in this guidance should be construed as negating the operator's statutory obligations or requirements under any other enactments, regulations or conditions of a CoR, WFP, Waste or IE licence.

4.1 Retail collection (distributors)

Given the relatively low quantity of waste batteries handled by distributors and the use of approved waste receptacles (e.g., WEEE Ireland battery boxes), the likelihood of a significant safety event due to the storage of small quantities of portable Li-ion batteries is considered low[27].

Retailers engaged in the collection of waste batteries should ensure that waste battery collection is integrated into their existing safety/fire risk assessment, Environment, Health and Safety (EHS) management systems and emergency response procedures.

A risk assessment should consider fire detection requirements, firefighting measures required as well as training to be implemented. The risk assessment may identify the need for additional measures (e.g., emergency plan, training, etc.) in response to the handling of waste Li-ion batteries, if not considered previously.

In the unlikely event that you become concerned about a safety issue regarding waste batteries, the following steps are advised:

- Call the emergency services immediately and seek medical advice if required;
- Notify your designated Workplace Health and Safety Officer immediately;
- Contact your Producer Responsibility Organisation (PRO) with feedback.

Further guidance and information on fire safety and emergency response are included in Sections 4.4 and 4.5.

4.2 Civic amenity sites

The following emergency preparedness measures are recommended for CA sites:

- Preparation of a Waste Storage Plan, APP and ERP (including Fire Response Plan), having regard to the recommendations for storage of waste Li-ion batteries (Section 3) and recommended measures for emergency response (Section 4.5);
- Fire Risk Assessment (FRA) to determine appropriate fire detection and firefighting equipment;
- Completion of a FRA (or screening as a minimum).

CA sites should also have regard to the separate EPA guidance "*Guidance for the Management of Household Hazardous Waste at Civic Amenity Sites*" (2017)[28].

Further guidance and information on fire safety and emergency response are included in Sections 4.4 and 4.5.

27 Lithium batteries and their safe storage, transport, use and disposal, including re-use and recycling, Scott Ian M B (published by IOSH)

28 https://www.epa.ie/publications/monitoring--assessment/waste/hazardous-waste/guidance-for-the-management-of-household-hazardous-waste-at-civic-amenity-sites.php

4.3 Waste treatment facilities

Licensed and Permitted sites will have specific contingency arrangements outlined in their respective authorisations. However, due to the increase in the generation of Li-ion battery waste, the potential for receipt of waste Li-ion batteries and appropriate control measures should be considered as part of the site or facility risk assessment.

Further guidance and information on fire safety and emergency response are included in Sections 4.4 and 4.5.

4.4 Fire safety

As noted previously, the EPA has published guidance[29] on fire safety at non-hazardous waste transfer stations, which should be read in conjunction with this guidance note where relevant. This guidance includes information on:

- Fire prevention;
- Fire detection and warning systems;
- Fire control and firefighting facilities;
- Fire escape, signage and lighting;
- Fire response planning and staff training;
- Post-fire actions.

A summary of the relevant fire safety guidance and additional fire safety measures specific to the handling of waste Li-ion batteries is included in Appendix C.

Further guidance is also available in the "*Fire Safety Guide for Building Owners and Operators*"[30] prepared by the Department of Housing, Local Government and Heritage (DHLGH).

4.5 Emergency response

4.5.1 Small Fires

For the purpose of this guidance document, small fires are those defined as localised and discrete.

Both sand and vermiculite are known to be highly effective materials in the prevention and control of small Li-ion battery fires. Where damaged or leaking batteries are encountered, the application of these non-toxic materials can provide basic but effective controls.

Boxes of vermiculite and sand (Figure 16) are recommended for waste disposal and recycling facilities handling waste Li-ion batteries routinely or as non-conforming waste. The number and locations of these boxes should have regard to areas where waste Li-ion batteries are most likely to arise (e.g., waste reception/unloading).

Sand can be applied to smother small fires, cutting off the oxygen. Sand also acts as an absorbent material which can contain hazardous or flammable liquids.

Vermiculite has exceptional thermal insulation properties and can help insulate/absorb heat while withstanding high temperatures without catching fire itself. Vermiculite can be applied to prevent the spread of heat from a battery that is overheating or on fire. Vermiculite is fire-resistant due to its mineral composition and structure and can also absorb liquids, such as those which may be released during the thermal runaway of a battery.

29 Guidance Note: Fire Safety at Non-Hazardous Waste Transfer Stations, EPA, 2013 (https://www.epa.ie/publications/compliance--enforcement/waste/EPA_Fire_Safety_Guidance_Note_WEB_FINAL_2.pdf)

30 Fire Safety Guide for Building Owners and Operators – Guide for persons having control under Section 18(2) of the Fire Services Acts 1981 and 2003, DHLGH, August 2023

Figure 16: Vermiculite and sand boxes

4.5.2 Large fires

Fighting larger lithium battery fires requires specialist training and equipment and will require the support of the external emergency services.

The UK Fire Industry Association has developed guidance on Li-ion battery fires[31], which may be consulted for further information.

4.5.3 Leaking battery/spill response

As with any compromised battery, a leaking battery should be handled with extreme caution. The following provides a sample protocol for spill response which can be aligned with existing spill response procedures:

- Isolate the area surrounding the leak, removing any sources of heat or ignition;
- Measures should be taken to ventilate the affected area;
- Check for any smoke generation, noting that chemicals released from certain batteries may pose an inhalation hazard;
- Absorb any of the leak with inert material (such as sand, or vermiculite);
- Using a tongs or non-conducting shovel and while wearing PPE, the leaking battery and any contaminated absorbent material should be placed in a suitable container, and removed to a quarantine area, which is designated to temporarily hold damaged or overheating batteries;
- The waste should be completely packed and covered with vermiculite or sand;
- Monitor the contained waste battery for signs of overheating, smoke, hissing, etc. before closing and sealing the waste container;
- This waste should not be mixed with other batteries or other types of waste and offsite disposal should be arranged at the earliest opportunity.

31 Guidance on Li Ion Battery Fires, UK FIA, 2020 (https://www.fia.uk.com/news/guidance-on-li-ion-battery-fires.html)

5.0 Resources

Resources and Other Guidelines

Waste Battery Presentation Guide, WEEE Ireland/ KMK Recycling
[Online: **https://www.kmk.ie/custom/public/files/waste-battery-presentation-guide.pdf**]

WEEE Ireland website (Waste Batteries)
[Online: **https://www.weeeireland.ie/health-safety/categories-of-waste/waste-batteries/**]

MyWaste website (Electrical, Electronic and Battery Waste)
[Online: **https://www.mywaste.ie/what-to-do-with-my-waste-electrical-and-electronic-equipment-weee/**]

Collection Point Battery Safety – Guideline for Safe Battery Recycling, WEEE Ireland
[Online: **https://www.weeeireland.ie/wp-content/uploads/2018/10/Weee_Ireland_Safety_Leaflet_Updated_Web_Tx_AW.pdf**]

Waste Classification – List of Waste and Determining if waste is hazardous or non-hazardous, EPA, 2019
[Online: **https://www.epa.ie/publications/monitoring--assessment/waste/waste-classification.php**]

Guidance for Retailers and Distributors of Electrical and Electronic Equipment (EEE) and Batteries, EPA, 2023
[Online: **https://www.epa.ie/publications/compliance--enforcement/waste/guidance-for-retailers-and-distributors-of-eee-and-batteries.php**]

Guidance for the Management of Household Hazardous Waste at Civic Amenity Sites, EPA, 2017
[Online: **https://www.epa.ie/publications/monitoring--assessment/waste/hazardous-waste/guidance-for-the-management-of-household-hazardous-waste-at-civic-amenity-sites.php**]

Guidance Note: Fire Safety at Non-Hazardous Waste Transfer Stations, EPA, 2013
[Online: **https://www.epa.ie/publications/compliance--enforcement/waste/EPA_Fire_Safety_Guidance_Note_WEB_FINAL_2.pdf**]

IPC Guidance Note on Storage and Transfer of Materials for Scheduled Activities, EPA, 2013
[Online: **https://www.epa.ie/publications/licensing--permitting/industrial/ied/materials-storage-guidance.php**]

Guidance to Licensees on the Preparation of Accident Prevention Procedures and Emergency Response Procedures, EPA, 2016
[Online: **https://www.epa.ie/publications/compliance--enforcement/licensees/reporting/EPA-2016-Guidance-on-APP-and-ERP.pdf**]

Carriage of Dangerous Goods by Road 2021, HSA, 2021
[Online: **https://www.hsa.ie/eng/publications_and_forms/publications/chemical_and_hazardous_substances/hsa_carriage_of_dangerous_goods_by_road_2021.pdf**]

Lithium Ion Battery Safety Guidance, Massachusetts Institute of Technology, March 2017 [Online: **https://ehs.mit.edu/wp-content/uploads/2019/09/Lithium_Battery_Safety_Guidance.pdf**]

Loss Prevention Standards – High Voltage Batteries, Aviva, 2020 [Online: **https://static.aviva.io/content/dam/document-library/risk-solutions/aviva_engineering_-_high_voltage_batteries_lps.pdf**]

Sharing Experiences and Best Practices with Batteries in WEEE, European Electronics Recycles Association, 2020 [Online: **https://www.weeeireland.ie/wp-content/uploads/2021/02/eera-shared-experiences-online-2-2-1.pdf**]

Battery Information Factsheet: Lithium-Ion (Li-Ion) Batteries, Recharge aisbl, 2021 [Online: **https://rechargebatteries.org/wp-content/uploads/2020/01/Li_Ion-BIF_EN-April-2021-PART-1-2-3-4.pdf**]

RC61 Recommendations for the Storage, Handling and Use of Batteries, UK Fire Protection Association, 2016 [Online: **https://www.thefpa.co.uk/advice-and-guidance/free-documents?=%20Medium-sized%20Businesses,%20MAINTENANCE%20CHECKLISTS%20-%20APPENDIX%20TEMPLATE%20FORMS,%20CONTROL%20OF%20DUST%20EXPLOSIONS&q=RC61%20RECOMMENDATIONS%20FOR%20THE%20STORAGE,%20HANDLING%20AND%20USE%20OF%20BATTERIES**]

RE2 Need to Know Guide – Lithium-ion Battery Use and Storage, UK Fire Protection Association, 2023 [Online: **https://www.thefpa.co.uk/advice-and-guidance/free-documents?q=RE2:%20Lithium-ion%20Battery%20Use%20and%20Storage**]

Information Document – Fire risk and lithium batteries at waste transfer, recycling and recovery operations (WISH INFO 08), UK Waste Industry Safety and Health Forum (WISH), 2019 [Online: **https://www.wishforum.org.uk/wp-content/uploads/2020/05/INFO-08.pdf**]

Recolight guidance for handling and storing waste batteries, Recolight (UK), 2017 [Online: **http://www.recolight.co.uk/wp-content/uploads/Recolight-guidance-for-handling-and-storing-waste-batteries-issued-2017.pdf]**

Lithium Battery Guidance Document – Transport of Lithium Metal and Lithium Ion Batteries. IATA, 2020 [Online: **https://www.iata.org/contentassets/05e6d8742b0047259bf3a700bc9d42b9/lithium-battery-guidance-document-2020.pdf**]

Guidance on Li Ion Battery Fires, UK Fire Industry Association, 2020 (Online: **https://www.fia.uk.com/news/guidance-on-li-ion-battery-fires.html**]

Fire Safety Guide for Building Owners and Operators – Guide for persons having control under Section 18(2) of the Fire Services Acts 1981 and 2003, Department of Housing, Local Government and Heritage, 2023 [Online: **https://www.gov.ie/en/publication/c0b05-fire-safety-guide-for-building-owners-and-operators/**]

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Muhammad Sheikh et al 2021 J. Electrochem. Soc. 168 030526. Internal Short Circuit Analysis of Cylindrical Lithium-Ion Cells Due to Structural Failure, 2021

Lithium batteries and their safe storage, transport, use and disposal, including re-use and re-cycling, Ian M B Scott

Teresa L. Barone, Thomas H. Dubaniewicz, Sherri A. Friend, Isaac A. Zlochower, Aleksandar D. Bugarski and Naseem S. Rayyan (2021) Lithium-ion battery explosion aerosols: Morphology and elemental composition, Aerosol Science and Technology, 55:10, 1183-1201, DOI: **10.1080/02786826.2021.1938966**

Herreras-Martínez, L., Anta, M., Bountis, R. (2021) et al. Recommendations for tackling fires caused by lithium batteries in WEEE- A report of the Batteries Roundtable.

Ollion, L., Anta, M., Herreras, L., Characterisation of fires caused by batteries in WEEE (2020), Survey results from the WEEE management chain – part A, a WEEE Forum and EuRIC report.

US Occupational Safety and Health Administration (OSHA) (2019) Safety and Health Information Bulletin – Preventing Fire and/or Explosion Injury from Small and Wearable Lithium Battery Powered Devices
[Online: **https://www.osha.gov/sites/default/files/publications/shib011819.pdf**]

Kong, Lingxi, Chuan Li, Jiuchun Jiang, and Michael G. Pecht. 2018. "Li-Ion Battery Fire Hazards and Safety Strategies" *Energies* 11, no. 9: 2191.
[Online: **https://doi.org/10.3390/en11092191**]

M. Held et al. Thermal runaway and fire of electric vehicle lithium-ion battery and contamination of infrastructure facility Renew. Sustain. Energy Rev. (2022)
[Online: **https://doi.org/10.1016/j.rser.2022.112474**]

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Energy Environ. Sci., 2021, 14, 6099. Environmental impacts, pollution sources and pathways of spent lithium-ion batteries
[Online: **https://pubs.rsc.org/en/content/articlelanding/2021/ee/d1ee00691f**]

Warner, J. (2019), Chapter 3 – Lithium-ion battery operation, Lithium-Ion Battery Chemistries, Pages 43-77.
[Online: **https://doi.org/10.1016/B978-0-12-814778-8.00003-X**]

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International – Template Rescue and Training Manual – Information for First and Second Responders and Fire Brigade in Storage Facilities – Lithium Batteries in a Storage Facility, CTIF/Recharge [Online: **https://rechargebatteries.org/wp-content/uploads/2020/03/RESCUE-AND-TRAINING-MANUAL-LITHIUM-BATTERY-IN-STORAGE-2014-12-05.pdf**]

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USA – Guide for Developing Lithium Battery Management Practices at Materials Recovery Facilities, Institute of Scrap Recycling Industries, Incl. (ISRI), National Waste and Recycling Association (NW&RA), and the Solid Waste Association of North America (SWANA), 2020 [Online: **https://www.isri.org/docs/default-source/default-document-library/mrf-lithium-battery-guidance.pdf?sfvrsn=2**]

USA – EPA Information – Used Lithium-Ion Batteries [Online: **https://www.epa.gov/recycle/used-lithium-ion-batteries**]

USA – Emergency Response Guidebook (ERG 2020) – Guide 147, US Pipeline and Hazardous Materials Safety Administration [Online: **https://cameochemicals.noaa.gov/erg_guides/en/Guide_147.pdf**]

Appendix A

Legislative Framework

International

Basel Convention

The Basel Convention[32] regulates the transboundary movements of hazardous wastes and other wastes and obliges its parties to ensure that such wastes are managed and disposed of in an environmentally sound manner. The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous wastes.

Among the principal aims of the Convention is the reduction of hazardous waste generation and the promotion of environmentally sound management (ESM) of hazardous wastes, wherever the place of disposal. The Convention also addresses the transboundary movement of hazardous waste.

At its most recent meeting of May 2023 (BC COP-16), the Conference of the Parties to the Basel Convention requested a working group to continue their work on draft technical guidelines on the ESM of waste batteries. Once finalised, the guidelines may also provide further guidance on the safe storage of Li-ion batteries at waste handling facilities.

European Legislation

Waste Framework Directive 2008/98/EC

The Waste Framework Directive 2008/98/EC (WFD)[33] aims to reduce the impact of waste through the establishment of a framework for waste management and the promotion of a circular economy. The WFD established a 'waste hierarchy', which prioritises the prevention of waste and the reuse of materials over recycling and disposal. The WFD also sets waste collection and recycling targets for Member States, with the primary target having been a 50% recycling and recovery target for household waste by 2020.

The amending Directive (EU) 2018/851 extends the targets originally set by the WFD on the reduction, collection and recycling of waste by EU Member States. The Directive includes provisions for the separation of waste streams for paper, metals, plastics, and biowaste, in order to facilitate their collection and recycling.

The primary targets are:

- A reduction in municipal waste to landfill by 10% by 2035;
- Increases in recycling of municipal waste to 55% by 2025, 60% by 2030, and 65% by 2035;
- Union-wide food waste reduction target of 30% by 2025 and 50% by 2030;
- Separate collection of textiles and hazardous waste generated by households by 2025.

32 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (revised in 2019)

33 Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

The amendment also extends the responsibilities of Member States to promote and communicate with consumers on issues of waste, through awareness campaigns and informing them of waste initiatives (collection schemes, incentives, etc.), as well as extending waste reporting requirements.

Battery Directive 2006/66/EC

The Battery Directive 2006/66/EC[34] established requirements within the EU for batteries (including waste batteries) to minimise risks to human health and the environment. The Directive banned the use of certain chemicals and set limits on hazardous substances contained in batteries, as well as setting labelling requirements to facilitate recycling and disposal of a battery's constituent parts.

The Battery Directive also requires EU Member States to implement distributor 'take back' and waste battery collection schemes and sets minimum targets for waste battery collection and recycling rates.

The Battery Directive has been amended, including by Directive 2018/849[35], which established monitoring and reporting requirements for Member States regarding collection targets for waste batteries, accumulators and EEE.

Further to the introduction in August 2023 of the Batteries Regulation, the Battery Directive is to be repealed as of 18 August 2025 (with certain obligations under the Directive to remain in force beyond this date as set out in the Batteries Regulation).

34 Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC

35 Directive 2018/849 – Amendment of Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment

WEEE Ireland and ERP (European Recycling Platform) Ireland are two established PROs, providing approved compliance services for battery producers and retailers in Ireland. Services provided by these bodies include collection and management of WEEE and waste batteries, ensuring achievement with statutory targets for recycling and recovery of WEEE, EPA reporting and maintenance of records. WEEE Ireland and ERP Ireland also provide a range of supports for the safe handling and management of waste batteries.

Batteries Regulation 2023/1542

The Batteries Regulation 2023/1542[36] entered into force in August 2023 in succession to the Battery Directive of 2006. The current provisions of the Directive will be replaced in a phased manner over the coming years in line with a number of timelines set out in the new Regulation.

The new Batteries Regulation seeks to ensure that, in the future, batteries have a low carbon footprint, use minimal harmful substances, require less raw materials from non-EU countries, and are collected, reused and recycled to a high degree in Europe.

The Batteries Regulation will ensure that batteries placed on the EU single market will only be permitted to contain a restricted amount of harmful substances that are necessary. Substances of concern[37] used in batteries will be regularly reviewed.

36 Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC.

37 Substances of concern are defined in the Chemicals Strategy for Sustainability (European Commission, 2020) as substances having a chronic effect for humans on the environment, such as substances in the candidate list for eventual inclusion in Annex XIV to Regulation (EC) No 1907/2006 and in Annex VI to Regulation (EC) No 1272/2008, but also those which hamper recycling for safe and high quality secondary raw materials, in the context of the substance evaluation planned in the REACH Evaluation Joint Action Plan published on the website of the European Chemicals Agency set up under Regulation (EC) No 1907/2006

Targets for recycling efficiency, material recovery and recycled content will be introduced from 2025 onwards.

Article 64 of the Regulation places an obligation on the end-users to discard waste batteries separately from other waste streams, including from mixed municipal waste.

Article 13(6) of the Regulation requires that all batteries will be marked with a QR code from 18 February 2027. This QR code will provide a range of information, including the following information on prevention and management of waste batteries:

- The role of end-users in contributing to waste prevention;
- The role of end-users in contributing to the separate collection of waste batteries in accordance with Article 64;
- Details of separate collection, take-back and collection points, preparation for re-use, preparation for repurposing and treatment options available for waste batteries;
- Safety instructions to handle waste batteries, including in relation to the risks associated with, and the handling of, batteries containing lithium;
- The meaning of the labels and symbols on batteries or printed on their packaging or in the documents accompanying batteries; and
- The impact of substances, in particular hazardous substances, present in batteries on the environment and on human health or the safety of persons, including the impact due to inappropriate discarding of waste batteries, such as littering or discarding as unsorted municipal waste.

The above measures will support greater awareness among end-users of the risks associated with waste batteries and improve compliance with the correct methods for discarding waste batteries.

From 18 February 2027, Article 77 of the Regulation also introduces the requirement for a digital battery passport (accessible via QR code) for certain larger batteries including LMT[38] batteries, industrial batteries with a capacity greater than 2 kWh and EV batteries. This digital passport will also be required to contain the above information on prevention and management of waste batteries. A battery passport will cease to exist after the battery has been recycled.

WEEE Directive 2012/19/EU

The Waste Electrical and Electronic Equipment (WEEE) Directive[39] (as amended) has several aims including to:

- Contribute to sustainable production and consumption by preventing the creation of WEEE as a first priority;
- Contribute to the efficient use of resources and the retrieval of secondary raw materials through re-use, recycling and other forms of recovery;
- Improving the environmental performance of everyone involved in the life cycle of EEE.

38 LMT = light means of transport battery i.e. a battery that is sealed, weighs 25 kg or less and is specifically designed to provide electric power for the traction of wheeled vehicles that can be powered by an electric motor alone or by a combination of motor and human power, including type-approved vehicles of category L within the meaning of Regulation (EU) No 168/2013 of the European Parliament and of the Council, and that is not an electric vehicle battery;

39 Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)

In order to achieve these objectives, the Directive requires the separate collection and proper treatment of WEEE and sets targets for their collection as well as for their recovery and recycling.

Article 8 of the WEEE Directive defines the proper treatment of WEEE, which includes minimum selective treatment requirements (as defined in Annex VII of the WEEE Directive). With the exception of preparing for re-use, the proper treatment of WEEE must include the removal of batteries from any separately collected WEEE.

Annex VIII of the WEEE Directive specifies the technical requirements for the storage and treatment of WEEE applicable to any establishment or undertaking carrying out collection or treatment operations. Sites for the treatment of WEEE are obliged to have appropriate containers for the storage of batteries.

The WEEE Directive also imposes a producer responsibility obligation in respect of WEEE management.

Landfill Directive 1999/31/EC

The objective of the Landfill Directive 199/31/EC[40] (as amended) is to prevent or reduce as far as possible, negative effects on the environment from the landfilling of waste by introducing strict technical requirements for waste and landfills.

While the Directive contains no explicit provisions relating to waste batteries, it is noted that Article 5(3)(f) of the Landfill Directive requires that Member States take measures to ensure that waste that has been separately collected for recycling, is not accepted in a landfill (with limited exceptions).

40 Council Directive 1999/31/EC of 29 April 1999 on the landfill of waste

The Restriction of Hazardous Substances (RoHS) Directive 2011/65/EU

The Directive[41] (as amended) restricts the use of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs) in new electrical and electronic equipment.

EU Transfrontier Shipment (TFS) Regulation (EC) No. 1013/2006

Regulation (EC) No. 1013/2006[42] (Transfrontier Shipment (TFS) Regulation or Waste Shipment Regulation (WSR)) and its amendments address the requirements of the Basel Convention. The WSR requires Member States to ensure that shipments of waste and their treatment operations are managed in a manner that protects the environment and human health against any adverse effects that might result from such wastes.

A revision of the EU TFS Regulation is currently underway.

Irish Legislation

Waste Management Act 1996

The Waste Management Act 1996, as amended, provides the legislative framework for waste and hazardous waste management in Ireland. The transposition of EU waste directives is enacted for the most part through enabling provisions included within the Act. The Environmental Protection Agency Act 1992, as amended, provides the framework for several other EPA functions, including the issuing of licences for certain industrial activities.

41 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

42 Regulation (EC) No. 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste (also referred to as the Transfrontier Shipment (TFS) Regulation or Waste Shipment Regulation (WSR))

Secondary legislation

S.I. No. 283 of 2014 – European Union (Batteries and Accumulators) Regulations 2014 (as amended) – governs the transport, recycling and disposal of waste batteries and accumulators and forms part of a Producer Responsibility Initiative (PRI), whereby the person or company that places the product on the Irish market has responsibility for financing the collection, storage, recycling and treatment of the product when it becomes waste. These regulations give effect to the provisions of European Parliament and Council Directive 2013/56/EU of 20 November 2013 amending Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators as regards the placing on the market of portable batteries and accumulators containing cadmium intended for use in cordless power tools, and of button cells with low mercury content.

S.I. No. 395 of 2004 – Waste Management (Licensing) Regulations 2004 (as amended) – provides for the issuing and enforcement of waste licences by the EPA.

S.I. No. 419 of 2007 – Waste Management (Shipments of Waste) Regulations (as amended) – streamlines the administration of Regulation (EC) No. 1013/2006 on the shipment of waste and establishes the National TFS Office (NTFSO) as the competent authority in respect of the import, export and transit of waste through Ireland.

S.I. No. 820 of 2007 – Waste Management (Collection Permit) Regulations 2007 (as amended) – provides for the issuing and enforcement of waste collection permits. The National Waste Collection Permit Office (operated by Offaly County Council) has responsibility for the issuing of collection permits.

S.I. No. 821 of 2007 – Waste Management (Facility Permit and Registration) Regulations 2007 (as amended) – provides for the issuing and enforcement of waste facility permits and certificates of registration for prescribed activities.

S.I. No. 113 of 2008 – Waste Management (Registration of Brokers and Dealers) Regulations – regulates waste contractors who arrange shipment of waste. A waste broker arranges to handle, transport, dispose of or recover controlled waste on behalf of others. Waste brokers include waste dealers who acquire waste and sell it on.

S.I. No. 126 of 2011 – European Communities (Waste Directive) Regulations 2011 (as amended) – transposes Directive 2008/98/EC on waste.

S.I. No. 324 of 2011 – European Communities (Shipments of Hazardous Waste exclusively within Ireland) Regulations 2011 – details the control of hazardous waste shipments in Ireland.

S.I. No. 349 of 2011 – European Communities (Carriage of Dangerous Goods by Road and Use of Transportable Pressure Equipment) Regulations 2011 (as amended) – applies to the transport of dangerous good by road in tanks, in bulk and in packages. The Regulations apply the provisions contained in the technical Annexes to the "Agreement Concerning the International Carriage of Dangerous Goods by Road" (ADR).

S.I. No. 513 of 2012 – European Union (Restriction of Certain Hazardous Substances in Electrical and Electronic Equipment) Regulations (as amended) – transposes the provisions of the RoHS Directive in Ireland.

S.I. No. 138 of 2013 – European Union (Industrial Emissions) Regulations (as amended) and S.I. No. 137 of 2013 – Environmental Protection Agency (Industrial Emissions) (Licensing) Regulations – these Regulations provide for the issuing and enforcement of licences by the EPA for Industrial Emission Directive activities.

S.I. No. 149 of 2014 – European Union (Waste Electrical and Electronic Equipment) Regulations 2014 (as amended) – gives effect to the provisions of Directive 2012/19/EU on WEEE.

S.I. No. 281 of 2014 – European Union (End-of-Life Vehicles) Regulations 2014 (as amended) – places specific obligations on vehicle owners, producers and authorised treatment facilities relating to the deposit, treatment and disposal of ELVs. Further amendments establish a mechanism for the introduction of the ELV compliance scheme in Ireland – ELVES.

S.I. No. 233 of 2015 – European Union (Properties of Waste which Render it Hazardous) Regulations 2015 – amends the Waste Management Act 1996 to replace the second schedule with a new schedule for the 'Properties of waste which render it Hazardous'.

S.I. No. 372 of 2016 – European Union (Waste Directive) (Recovery Operations) Regulations allows for the substitution of the fourth schedule, Recovery Operations, of the Waste Management Act 1996 with a new fourth schedule for recovery operations.

S.I. No. 383 of 2018 – European Union (Properties of Waste which Render it Hazardous) Regulations 2018 – amends the Waste Management Act 1996 to replace 'Ecotoxic' in the second schedule.

S.I. No. 321 of 2020 – European Union (Landfill) Regulations 2020 – gives effect to Directive (EU) 2018/8501 of the European Parliament and of the Council of 30 May 2018 amending Directive 1999/31/EC2 on the landfill of waste. The aim of these Regulations is to ensure a progressive reduction of landfilling of waste, in particular of waste that is suitable for recycling or other recovery; provide for measures to prevent or reduce as far as possible negative effects on the environment from landfilling of waste, during the whole life cycle of the landfill.

S.I. No. 323 of 2020 – European Union (Waste Directive) Regulations 2020 – gives effect to Directive 2018/851 of the European Parliament and of the Council of 30 May 2018 on waste and amending certain directives giving effect to provisions of the Waste Directive and partial effect to the Batteries, ELV, WEEE, Packaging and Landfill Directive(s).

Appendix B

Li Ion Battery Hazards – Potential Consequences

Thermal runaway

Faults in a waste Li-ion battery can result in 'thermal runaway' with the associated risk of an intense fire which has potential to rapidly increase beyond control. A common cause of thermal runaway is a short circuit event as described in Section 2.3.1 previously.

Thermal runaway occurs when a cell has reached the temperature at which the temperature will continue to increase on its own, as it creates oxygen which feeds the fire[43]. Thermal runaway results in a series of chemical reactions (domino effect) that will lead to additional generation and release of gases, sparks or even the release of oxygen outside the cell. Signs of thermal runaway include overheating, hissing, or bulging of the battery.

Once the temperature of the cell reaches about 80°C, the layer protecting the anode begins to decompose and break down generating heat due to the reaction of lithium with the solvents used in the electrolyte. At about 100-120°C the electrolyte begins to break down in another reaction liberating heat, which in turn generates various gases within the cell. The gases that may be created during this reaction, depending on cell chemistry, include carbon dioxide, carbon monoxide, methane, ethane, ethylene and hydrogen. As the temperature nears 120-130°C, the separator (layer separating anode and cathode) eventually melts, allowing the anode and cathode electrodes to make contact and cause an internal short circuit, generating more heat. As the temperature continues to rise, between approximately 130-150°C, the cathode begins to break down in another chemical reaction that liberates heat with the electrolyte, which also generates oxygen. It is this release of oxygen along with the carbonate LiPF6[44] electrolyte that ultimately allows the cell to burn out and catch fire. The decomposition of the cathode active material is a highly exothermic reaction that generates a lot of heat and continues to drive the cell toward ultimate failure and fire.

When temperatures rise above 150-180°C, the reaction may become self-sustaining if the cell fails to rapidly dissipate the heat being generated. At this point, the cell is in a state of 'thermal runaway', as the oxygen generation makes the fire self-sustaining until all the fuel has been consumed. If gases continue to build up inside the cell, the cell may rupture or vent through a safety valve, expelling flammable hydrocarbon gases and hydrofluorocarbon electrolytes at this point. The introduction of a spark could ignite the electrolyte and the gases, causing flame, fire and potentially an explosion. If the pressure continues to increase, it is also possible that the cell will burst open and eject the "jellyroll" from the housing[45].

43 Warner, J. (2019), Chapter 3 – Lithium-ion battery operation, Lithium-Ion Battery Chemistries, Pages 43-77. [Online: https://doi.org/10.1016/B978-0-12-814778-8.00003-X]

44 Lithium hexafluorophosphate (LiPF6) is a widely used salt in the electrolytes for commercial lithium-ion cells.

45 Wang, O., Zhao, P.P.X., Sun, G.C.J., Chen, C. (2012), Thermal runaway caused fire and explosion of lithium-ion battery, Journal of Power Sources, Volume 208, Pages 210-224. [Online: http://www.sciencedirect.com/science/article/abs/pii/S0378775312003989]

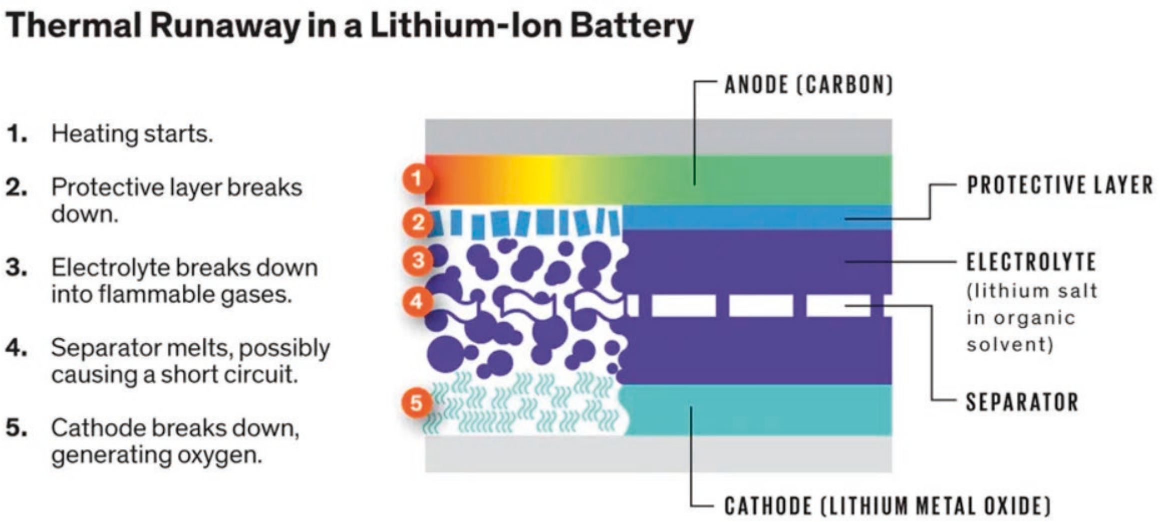

Figure B.1: Thermal Runaway in Li-ion Battery Cell[46]

The onset temperature for the reactions to liberate heat and to drive thermal runaway varies with the chemistry of the battery cells and their state of charge. In general, the higher the cell voltage or the state of charge, the lower the thermal runaway start temperature. For battery cells with the same chemistry, it varies with the load history of the specific cell and any damage caused to the battery[47]. Temperatures over 170°C may trigger explosions which could quickly increase to temperatures up to 700-800°C[48].

These temperatures pose a risk of thermal burn injuries if the battery or battery components come into contact with human skin. In addition to the thermal burn risk associated with the extreme exothermic reaction, the corrosive materials found in Li-ion batteries can also cause chemical or electrical burns through contact battery materials on the skin.

46 Ross, PE. (2013), Boeing's Battery Blues. [Online: http://dx.doi.org/10.1109/MSPEC.2013.6471040]

47 Bandhauer, TM., Garimella, S., Fuller, TF. (2011), A critical review of thermal issues in lithium-ion batteries, Journal of the Electrochemical Society, Volume 158, Number 3. [Online: http://dx.doi.org/10.1149/1.3515880]

48 Presentation SENS Foundation. WEEE Forum Operations Committee, 3 December 2020.

Venting

Venting describes the process whereby gases are released from the battery in response to overheating, physical damage, or decomposition when a battery has expired. This can cause swelling of the battery, as internal pressure builds and poses a risk of thermal runaway. Audible sounds ('clicks' or 'puffs') may be produced as the internal pressure releases.

Above a certain temperature (~69°C), the electrolyte begins to evaporate, increasing the pressure inside the battery leading to swelling or rupturing of the battery casing. The gas discharging from the battery is flammable and may ignite. In the most severe cases, the battery may explode.

When a cell vents the released gases mix with the surrounding atmosphere. Depending upon a number of factors, including fuel concentration, oxygen concentration and temperature, the resulting mixture may or may not be flammable.

Many batteries have built-in safety features, so called 'fail-safes', to reduce the risk of fire or explosion as a result of battery venting. Safety vents or pressure relief devices can release internal pressure and temperature in a controlled manner, and thermal fuses can break the cycle of increasing internal temperature associated with thermal runaway. Other battery designs do not feature such safeguards and it cannot be assumed that all waste Li-ion batteries incorporate a safety vent/pressure relief device.

Although the proportions and concentrations of emitted gases are dependent on the material composition of the battery itself, the 'state of charge' of the battery, and the point at which the battery is in its life cycle, gases released generally consist of hydrogen, carbon monoxide and dioxide, hydrocarbons, with lower concentrations of toxic gases such as fluoro-organic compounds.

Release of potentially hazardous substances

Although Li-ion batteries contain hazardous substances, the batteries themselves are not considered hazardous when sealed and intact. However, as Li-ion batteries contain heavy metals such as nickel and cobalt, if the battery casing is damaged and the contained substances released, these can cause environmental pollution and damage to human health.

Some common examples of the hazardous substances used in Li-ion batteries are listed in Table B.1:

Table B.1: Common materials used in Li-ion batteries with associated hazard codes and statements

Chemical name	CAS number	Hazard code	Hazard statement
Electrolyte salt			
Lithium hexafluorophosphate	21324-40-3	H301	Toxic if swallowed
		H314	Causes severe skin burns and eye damage
		H372	Causes damage to organs through prolonged or repeated exposure
Coating			
Polyvinylidene Fluoride (PVDF)	24937-79-9	NA	
Polyvinyl acetate	9003-55-8	NA	
Electrolyte solvents			
Ethylene Carbonate	96-49-1	H302	Harmful if swallowed
		H319	Causes serious eye irritation
		H373	May cause damage to organs through prolonged or repeated exposure
Propylene Carbonate	108-32-7	H319	Causes serious eye irritation
Diethyl Carbonate	105-58-8	H226	Flammable liquid and vapour
		H315	Causes skin irritation
		H319	Causes serious eye irritation
		H335	May cause respiratory irritation
Dimethyl Carbonate	616-38-6	H225	Highly flammable liquid and vapour

Chemical name	CAS number	Hazard code	Hazard statement
Ethyl Methyl Carbonate	623-53-0	H226	Flammable liquid and vapour
		H315	Causes skin irritation
		H319	Causes serious eye irritation
		H335	May cause respiratory irritation
Ethyl-Acetate	141-78-6	H225	Highly flammable liquid and vapour
		H319	Causes serious eye irritation
		H336	May cause drowsiness or dizziness
Cathode			
Cobalt oxide	1307-96-6	H302	Harmful if swallowed
		H317	May cause an allergic skin reaction
		H400	Very toxic to aquatic life
		H410	Very toxic to aquatic life with long lasting effects
Manganese oxide	1344-43-0	H302	Harmful if swallowed
		H332	Harmful if inhaled
Nickel oxide	1313-99-1	H350i	May cause cancer by inhalation
		H372**	Causes damage to organs through prolonged or repeated exposure if inhaled
		H317	May cause an allergic skin reaction
		H413	May cause long lasting harmful effects to aquatic life
Lithium Cobaltite	12190-79-3	H317	May cause an allergic skin reaction
		H350	May cause cancer
Manganese	7439-96-5	H260	In contact with water releases flammable gases which may ignite spontaneously
Nickel	7440-02-0	H250	Catches fire spontaneously if exposed to air
		H317	May cause an allergic skin reaction
		H351	Suspected of causing cancer
		H372	Causes damage to organs through prolonged or repeated exposure
Aluminium	7429-90-5	H250	Catches fire spontaneously if exposed to air
		H261	In contact with water releases flammable gas
Anode			
Copper	7440-50-8	H411	Toxic to aquatic life with long lasting effects
Graphite	7782-42-5	NA	NA
Carbon Black	1333-86-4	NA	NA

Fire impact

Fire events involving Li-ion batteries present a number of dangers for human health and safety, particularly for personnel within a waste handling facility. Li-ion fires have potential to be extremely hot, fast burning and can be difficult to extinguish.

Fire impingement (direct flame contact) on lithium cells will cause release of flammable electrolyte, increasing the total heat release of a fire.

In the event of fire, the release of irritating, corrosive and/or toxic gases as well as dust is to be expected. As Li-ion batteries commonly contain fluorine, the risk of toxic hydrogen fluoride gas production when exposed to fire is of particular concern to health and safety. Conductive salts can decompose when moisture enters and, with fire, produce hydrofluoric acid.

Smoke from thermal runaway in a Li-ion battery is both flammable and toxic. Fumes may cause dizziness or asphyxiation.

Explosion

In the event of an explosion as a result of battery gas venting, debris and hazardous material can be scattered violently with the risk of thermal and chemical burns (particularly when in enclosed spaces). In addition, to the human health and safety risks, the force of a battery explosion has the potential – in significant cases – to cause major property damage with associated losses and business disruption.

Hydrogen fluoride is a corrosive and toxic gas released when a Li-ion battery explodes, forming hydrofluoric acid when released in the presence of water. Inhalation poses a particular risk to human health in the immediate aftermath of a Li-ion battery explosion, particularly in confined spaces[49].

Electric shock

High voltage Li-ion batteries (such as those used in electric vehicles) present a serious electrical shock hazard, even when the battery is partially or fully discharged. To avoid serious injury or fatality from electric shock, the high voltage battery assembly cover should never be breached under any circumstance.

49 Yoo Jung Park, Min Kook Kim, Hyung Sik Kim and Byung Mu Lee (2018) Risk Assessment of Lithium-Ion Battery Explosion: Chemical Leakages. Journal of Toxicology and Environmental Health, Part B 21 (6–8): 370–381. doi:10.1080/10937404.2019.1601815

Appendix C

Summary of Fire Safety Measures

Table C.1 provides a summary of fire safety measures which can be implemented at waste handling facilities in support of the management of waste Li-ion batteries. This table has been prepared having regard to existing relevant guidance[50] for fire safety at non-hazardous waste transfer stations, with additional recommended measures for Li-ion batteries incorporated based on relevant guidelines reviewed (Section 5) as part of this guidance note.

The applicable measures will be dependent on the scale and nature of waste management activities at the site, quantities and types of waste handled and the prevalence of Li-ion batteries, either as acceptable waste (for those facilities licensed or permitted to accept waste batteries) or non-conforming waste. Suitably qualified and experienced facility designers and fire safety specialists can advise on the specification of fire safety equipment for new facilities or modifications to existing facilities.

A site-specific FRA is recommended to identify and document the appropriate measures.

50 Guidance Note: Fire Safety at Non-Hazardous Waste Transfer Stations, EPA, 2013 (https://www.epa.ie/publications/compliance--enforcement/waste/EPA_Fire_Safety_Guidance_Note_WEB_FINAL_2.pdf)

Table C.1: Summary of good practice fire safety measures for Li-ion batteries at waste handling facilities

Component of Fire Safety	Fire Safety Measures
Fire prevention	■ Control of ignition sources and segregation from waste battery storage e.g., heating pipes, naked flames, light bulbs, space heaters, furnaces/incinerators; • Keep potential ignition sources at least 6 m away from battery waste and other combustible and flammable materials. ■ Ensure controls and procedures in place for hot working such as welding and cutting; ■ Ensure all visitors receive appropriate fire safety information/training as part of induction or site visit protocol; ■ Ensure a no-smoking policy in areas of battery storage; ■ Ensure regular maintenance/inspection and housekeeping of all waste storage areas; ■ Ensure site security measures in place during working and silent hours to prevent arson e.g., fencing, intruder alarms/CCTV; ■ Site vehicles equipped with fire extinguishers and dust filters; ■ Ensure bucket loaders are fitted with rubber strips to prevent sparks being generated when the bucket comes into contract with hard-standing, etc.; ■ Consider implementing a fire-watch at the end of the shift; ■ Appropriate siting of waste quarantine area for damaged batteries; ■ Manage size and spacing of waste stockpiles; ■ No tipping from height of waste materials having potential to contain Li-ion batteries; ■ Waste acceptance/inspection procedure to include provision for the identification and segregation of waste Li-ion batteries from mixed waste intake.
Fire detection and warning systems	■ Installation of fire detection and alarm system: • Heat, smoke and/or flame detectors ■ Back-up power supply for fire-detection and warning system; ■ Inspection and maintenance regime for fire detection and warning systems; ■ Automatic fire detection; ■ Manual break-glass units; ■ Fire safety procedures to consider lone working and silent hours; ■ Regular inspections and visual checks of known fire risk areas, including waste unloading and battery storage areas; ■ Remote monitoring (e.g., CCTV) of larger waste processing areas; ■ Visual and audible alarms, considering strobe lights in noisy areas.

Component of Fire Safety	Fire Safety Measures
Fire control and firefighting facilities	■ Compartmentation; • Internal subdivision of a building into fire compartments to limit the potential for a fire to spread; ■ Firewalls and smoke screens; ■ Separation of waste treatment and waste storage areas; ■ Segregation of materials – untreated WEEE, treated fractions and batteries in dedicated areas; ■ Waste bunkers of fire-resistant design; ■ Fire suppression: • Provision and maintenance of supplies of sand and vermiculite for the control of damaged or leaking batteries, incipient/small battery fires; • Portable hand-held extinguishers; • Fixed firefighting equipment (e.g., hose reels, sprinklers, foam systems, turret extinguishing systems); • Gas or foam monitors/flooding systems; • Machinery on hand to remove burning material (e.g., scrap handler with extension arm); • Selection of firefighting media using FRA; ■ Access for fire brigade appliances. All firefighting equipment should be subject to a programme of inspection and maintenance.
Fire escape, signage and lighting	■ Means of escape; • Keep fire exit routes and doorways clear and free of obstruction, slip or trip hazards; • Waste battery storage and combustible materials should not be stored in proximity to the escape routes/doorways. ■ Exit signage and wayfinding; ■ Emergency lighting to illuminate escape routes, wayfinding signage exit doors, safety equipment and key control equipment.

Component of Fire Safety	Fire Safety Measures
Fire response planning and staff training	**Fire Response Plan** ■ Information on the following: • Communication arrangements; • Types, quantities and properties of combustible and other hazardous materials on the site; • Number of people working on the site (staff and contractors) and any differences that may occur in occupancy (e.g., shift patterns, weekdays/weekends, public holidays, etc.); • Number and types of heavy plant and machinery; • Details of Emergency Response Team and number of personnel trained in fire response; • Likely burn times of material; • Procedures for disposal of firewater and any other waste arising during a fire. ■ Site plan • Layout of buildings; • Hazardous areas on site (including waste battery storage/quarantine); • Main access routes for fire engines and alternative accesses (if available); • Access points around the site perimeter to assist firefighting; • Hydrants and water supplies; • Any watercourse, borehole or well located within or near the site; • Areas of natural and unmade ground; • Location of plant and pollution prevention equipment and materials; • Drainage systems, including foul and surface water drains and direction of flow; • Location of drain cover and pollution control features such as firewater containment systems; ■ Procedures staff should follow if a fire starts, including measures which address: • Actions to be taken during the period before and after the fire services arrive; • Any differences in the arrangements which apply during and outside normal working hours; • The person(s) responsible for consultation with the relevant fire services and when.

Component of Fire Safety	Fire Safety Measures
Fire response planning and staff training *(continued)*	**Staff Fire Safety Training and Awareness** ■ Fire safety training provision by a competent person: ■ All staff (full and part-time including contractors) to be trained in the following matters: • Action to be taken upon discovering a fire; • Raising the alarm, including the locations of alarm indicator panels, break glass units, etc.; • Details of fire alarm and action to be taking upon hearing or seeing the alarm; • How the fire and rescue service (and any other agencies) will be called and who is responsible for external contact; • Location of firefighting equipment; • Knowledge of all escape routes; • Importance of fire doors; • Building/site evacuation procedure; • Stopping machines, processes, key control equipment, isolating power supplies (where appropriate); • Assembly points and procedure for confirming evacuation; • Arrangements for firefighting; • Duties and identify of staff who have specific responsibilities if there is a fire; • Specific arrangements for high-risk fire areas, including waste battery storage; • Contingency plans if life safety systems are compromised or not working (e.g., fire detection and alarm, sprinklers, smoke control, etc.); • Procedures for meeting the fire and rescue service on arrival and notification of any special risks (including the location of battery waste and other flammable materials). ■ Induction training for new staff to include instruction on what to do in the event of discovering a fire, hearing/seeing an alarm, walk over of escape route; ■ Additional training/interpreter if employee's language is not English; ■ Training materials – handouts, leaflets, instructions, videos, etc.; ■ Refresher training at appropriate intervals on fire precautions and emergency response; ■ Oversight of contractor management and third-party fire safety training; ■ Record keeping – fire safety training; ■ Specialist training e.g., members of site Emergency Response Team, use of firefighting equipment, etc.; ■ Permit to work system, including hot work permits; ■ Housekeeping and battery storage segregation.

<table>
<tr><th>Component of Fire Safety</th><th>Fire Safety Measures</th></tr>
<tr><td>Fire response planning and staff training (continued)</td><td>Fire Routine
■ Devise Fire Routine considering the uses to which the premises are put and the means of giving warning and means of communication;
■ All staff should be familiar with the Fire Routine;
■ ‘Fire instruction’ notices stating, in concise terms, the essential actions to be taken upon discovering a fire and on hearing the fire alarm – exhibited at conspicuous positions in all parts of the building(s);
■ Key members of staff assigned specific roles as part of the Fire Routine;
■ Fire authority or specialist fire safety consultant engagement to inform the Fire Routine.</td></tr>
<tr><td>Post fire actions</td><td>Fire and Accident Investigation
■ Initiate incident investigation and support any investigations by external agencies;
• In the event of a fire or accident resulting in injury or death, or if a malicious cause is suspected, the fire brigade will secure and preserve the site for investigation;
■ Site ERP to consider for external agency liaison;
■ Incident notification to regulatory authorities including EPA, HSA and other relevant agencies (e.g., local authority, Inland Fisheries Ireland, etc.);
■ Measures to secure the site for insurer/nominated loss-adjuster examination.

Safety issues
■ Measures for building inspection prior to re-entry of personnel and visitors;
■ Measures for clean-up, repair and/or demolition, reconstruction, etc.;
■ Engagement with all other waste service providers necessary for clean-up and/or remediation of toxic product releases due to the fire, including waste characterisation as necessary.

Firewater
■ Completion of firewater risk assessment in accordance with EPA guidance[51];
■ Contingency plans for contaminated firewater disposal;
■ EPA/local authority incident notification to address contaminated wastewater disposal;
■ Review and update of FRA and Fire Response Plan to incorporate corrective and preventative actions identified following incident investigation.</td></tr>
</table>

51 Guidance Note to Industry on Fire Water Retention Facilities, EPA (2019) (https://www.epa.ie/publications/licensing--permitting/industrial/ied/guidance-note-to-industry-on-fire-water-retention-facilities.php)

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