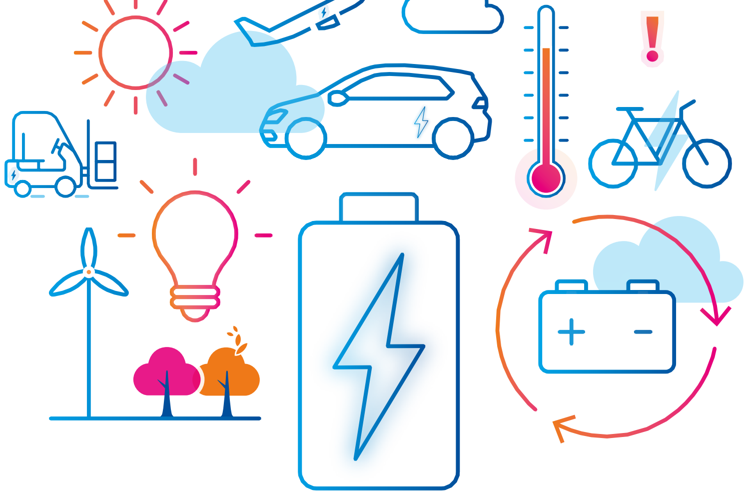

Health risks associated with Lithium and Lithium-ion batteries

Lithium batteries are in common use in a variety of industrial and consumer settings – and convert chemical energy into electrical energy to store energy.

Each battery cell contains a positive electrode (also known as a cathode) and a negative electrode (also known as an anode). Between the two electrodes is a separator layer comprising an electrolyte that allows electrons or ions to flow between them.

Types of batteries

There are two types of batteries - Primary and Secondary. Primary batteries are non-rechargeable and are frequently referred to as single-use batteries. These batteries are very energy-dense, can store and emit power for long periods of time, and are used in watches, smoke detectors, and pacemakers – all of which need constant and continuous power. Secondary batteries are rechargeable. In lithium-ion batteries, the ions inside the battery can move in two directions: from the anode to the cathode while discharging and from the cathode to the anode when recharging.

Rechargeable lithium ion (Li-ion) batteries are used in mobile phones and laptops, and larger versions power electric vehicles (EV) and cars in particular. There are two different types of lithium-ion (alkaline) rechargeable batteries: valve-regulated ('maintenance-free') and vented.

In valve-regulated batteries, any hydrogen and oxygen produced during charging does not escape from the body of the battery but is converted back into water. The battery is sealed and does not require topping up with water.

Vented batteries allow any hydrogen and oxygen produced to escape into the surrounding atmosphere. They require regular topping up with water.

Health hazards associated with lithium and lithium-ion batteries

Recently, there has been much in the professional and domestic media regarding fires which have occurred during charging of smartphones, scooters, and electric vehicles and during the waste handling and recycling of lithium and lithium-ion batteries.

Hydrogen and oxygen are usually produced inside a battery when it is being charged. A source of ignition – for example, a flame, a spark, a cigarette or any hot object, electrical equipment, will often cause mixtures of these gases to ignite and explode. The explosion is often so violent that it shatters the battery and produces a highly dangerous shower of fragments and corrosive chemicals.

Perhaps less well understood however, are the health hazards associated with the lithium and other hazardous substances contained within these types of batteries. Although contact with these materials is unlikely when handling batteries in a controlled manner, if the integrity of the battery housing is damaged, or the battery catches fire or explodes, contact with the substances described below may occur. This is of particular significance when considering emergency preparedness and post-event clean-up activities.

Aluminium, copper, cobalt, iron, and lithium are the five key metals of lithium and lithium-ion batteries, and together with hydrogen fluoride and acids are the predominant hazardous substances likely to be encountered.

Hydrogen fluoride and Hydrofluoric acid

Lithium-ion batteries contain fluorine, which readily combines with hydrogen to generate hydrogen fluoride (HF).

HF can exist as a colourless gas or fuming liquid, or it can be dissolved in water. When hydrogen fluoride is dissolved in water, it may be known as hydrofluoric acid.

Hydrofluoric acid is a highly toxic, reactive chemical. Skin contact with diluted solutions can cause very serious and extremely painful burns. The extent of these burns can readily be missed at the initial stage, as it can take up to 24 hours after contact before the pain is felt. The acid is also capable of destroying flesh long after initial efforts have been made to wash it from the skin. Very small quantities of diluted hydrofluoric acid can cause irreparable damage to the eye, and it is toxic by inhalation.

Lithium batteries are readily prone to overheating by means including spontaneous internal/external short-circuiting, over-charging, mechanical damage, and external heating.

This overheating may cause the electrolyte in the battery to evaporate with the resulting gas being vented out with the battery. If this happens, the gas may ignite immediately, or build up giving rise to a serious risk of imminent explosion.

Ignition of the battery liberates a number of toxic substances including HF and intermediate compounds such as phosphoryl chloride and phosphoryl fluoride. Whilst these are predominantly the products of the thermal breakdown of the electrolyte, fluorine may be present in the fabric of the battery, for example in flame retardant coatings. These substances will react with organic materials and ultimately with water, resulting in the generation of hydrofluoric acid.

Carbon monoxide and carbon dioxide

Ignition of batteries also results in the liberation of carbon monoxide and carbon dioxide.

Both these gases interfere with the absorption and transport of oxygen around the body, leading to oxygen deprivation of its tissues and organs.

If sufficient oxygen is prevented from circulating in the bloodstream and transferring to cells, it can result initially in fatigue, clumsiness, breathlessness, confusion, and an increase in heart rate. If exposure continues, or is at an increased level, symptoms include nausea, vomiting, convulsions, coma, and death.

Lithium

Lithium is a soft, silver to grey/white metal which is odourless and becomes yellow if exposed to air.

It can severely irritate and burn the skin and eyes and inhaling it can cause irritation of the lung.

Lithium becomes corrosive when in contact with moisture, so higher levels of inhalation to it may cause a build-up of fluid in the lungs leading to pulmonary oedema which requires urgent medical attention.

Cobalt

Cobalt is a hard, bluish-white metal. At high temperatures, it is attacked by atmospheric oxygen and by water vapour, producing cobalt (II) oxide.

Routes of entry into the body for cobalt include inhalation and skin contact with dusts or solutions containing cobalt, or via ingestion, through handling food if hands are contaminated with it. Short-term effects can include vomiting and abdominal pain if cobalt salts are ingested.

Nickel

Nickel is a silvery-grey metal which is used mainly in alloys with other metals.

Nickel can enter the body via inhalation of dust, fumes or mist containing nickel, and via skin contact with dust or solutions containing nickel.

The toxicity of nickel metal and inorganic nickel compounds vary depending on their solubility. However, general short-term effects can include irritation of the skin on contact with solutions of soluble nickel salts; eye irritation from exposure to nickel dust, fumes, or splashes from nickel-containing solutions.

Copper

Owing to its heat and electrical conductivity as well as its resistance to corrosion, ductility, and malleability, copper has many industrial applications and is widely used in electrical wiring and switches.

Occupational exposure to copper is usually via inhalation and ingestion.

Inhalation of copper fume can lead to metal fume fever, which is characterised by symptoms such as fever, headache and tiredness, as well as cough, sore throat and tightening of the chest.

Ingestion of food and liquids containing high levels of copper or contaminated with it can cause stomach pain, nausea, vomiting and diarrhoea. Symptoms usually resolve once the exposure stops.

Aluminium

Aluminium is an odourless, lightweight, silvery-white metal.

Aluminium powder is flammable and given an ignition source can ignite on contact with air. A dust explosion is possible if the powder or granular forms mix with air, and aluminium powder reacts with alcohols and water. It also reacts violently with oxidants, strong acids, strong bases and chlorinated hydrocarbons causing a fire and explosion hazard.

Routes of entry into the body include ingestion and inhalation. Inhalation of aluminium dust can cause irritation of the respiratory tract, whilst ingestion may result in burning in the mouth and throat and mild gastrointestinal upset, and in severe cases, ulceration of the lips and mouth can occur.

Acids

Batteries are usually filled with solutions (electrolytes) containing either sulphuric acid or potassium hydroxide. These are very corrosive chemicals and can permanently damage the eyes and produce serious chemical burns to the skin. Sulphuric acid and potassium hydroxide are also poisonous if swallowed.

(Longer term health effects can result from exposure to all of the above materials, however, they are not addressed in this document as exposure to them in the context of battery manufacturing is likely to be acute rather than chronic.)

Control measures

Control measures selected and implemented will be guided by the risk assessment of relevant tasks involving lithium and lithium-ion batteries. However, they are likely to include:

Suitable local exhaust ventilation of the charging area when identified through risk assessment. The risk assessment process may also identify a requirement to wear suitable personal protective equipment including gloves, eye protection, boots, and apron.

Segregation of the charging area with authorised personnel only being permitted access.

Avoiding keeping metal objects in any pockets which could fall out and onto the battery or bridge across its terminal.

Keeping sources of ignition such as flames, sparks, electrical equipment, hot objects, and mobile phones well away from batteries that are being charged, have recently been charged, or are being moved.

Using suitable single-ended tools with insulated handles, and fit temporary plastic covers over the battery terminals.

Avoiding overcharging batteries and ensure that those in storage are held at levels of less than 50% of their charging capacity, and at temperatures between 4 – 27 degrees centigrade. This will minimise the risk of overheating and ignition which may be caused by internal short-circuiting or manufacturers' defects.

Ensuring hand washing facilities with warm water are available.

In addition to undertaking a risk assessment and implementing controls such as those referenced above, a comprehensive procedure to prepare for emergency events should be developed in consultation with relevant employees.

The procedure should be trained so that those working with batteries have a thorough understanding of actions they should take. The procedure should address any specialist clean-up of released materials.

If exposure to hydrofluoric acid is possible, a readily-accessible and in-date supply of the antidote to this – calcium gluconate gel, should be maintained in the work area. Whilst suitably trained first aiders can administer the gel, in view of the severity of the effects of exposure to hydrofluoric acid and the swiftness with which it is desirable to apply the antidote, consideration should be given to having individuals trained in its application in each area where exposure may occur.

The table below provides typical hazard information concerning lithium and lithium-ion batteries. This information is commonly found within the associated lithium or lithium-ion battery material safety data sheet (MSDS). However, please note that this information may differ depending on the type of battery in operation.

Health Hazards

Typical battery MSDS categories

- Flammable Liquids (Category 3) H226
  Flashpoint 38°C to 60°C
- Acute Toxicity, Oral (Category 4) H302
  Harmful if inhaled, on skin contact or if swallowed
- Skin corrosion (Category 1A) H314
  Destruction of skin tissue
- Serious eye damage (Category 1) H318
  Irreversible effects on the eye
- Specific target organ toxicity - single exposure

  Respiratory system H335
  May cause respiratory irritation
- Specific target organ toxicity - repeated exposure

  Inhalation (Category 1)
  highest toxicity category

  Bone & Teeth H372
  Damages organs, bone, teeth if prolonged or repeated exposure if inhaled

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