OHIO DEPARTMENT OF HEALTH
BATTERY ENERGY STORAGE
SUMMARY AND ASSESSMENTS

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Last Updated April 11, 2022

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Introduction

The Ohio Department of Health's (ODH) role in the Ohio Power Siting Board has historically been to assess cases to determine whether the construction, alteration, operation, or decommissioning of any power-generating structure or facility will have an impact on the health and wellness of the public. ODH works in partnership with fellow state agencies, including the Ohio Department of Natural Resources (ODNR), which assesses ecological impacts, and the Ohio Environmental Protection Agency (OEPA), who is responsible for environmental licensing and regulation, to provide a robust, holistic assessment.

The purpose of this ODH document is to assess, based upon existing research and published information, whether battery energy storage devices have the potential to cause harm to human health. ODH has developed this document at the request of the Ohio Power Siting Board in response to an increase in the construction of new solar power and wind turbines facilities in Ohio which may apply this technology to supply the power grid during periods when power generation sources are not available.

The determinations within this document were made based upon a review of literature available at the time of its original publication. As scientific information changes over time, and battery technologies and within Ohio changes, ODH will reevaluate these conclusions as needed. ODH did not conduct independent, peer-reviewed research in order to produce this document.

Batteries are a range of electrochemical storage devices which include advanced chemistry batteries, flow batteries, and capacitors (Energy Storage Association Website, 2021).

Lithium Ion Batteries

The term "lithium ion" refers not to a single electrochemical couple but to a wide array of different chemistries, all of which are characterized by the transfer of lithium ions between the electrodes during the charge and discharge reactions. Li-ion cells do not contain metallic lithium; rather, the ions are positive electrode (cathode) and carbon (typically graphite) or lithium titanate in the negative (anode) (Energy Storage Association Website, 2021).

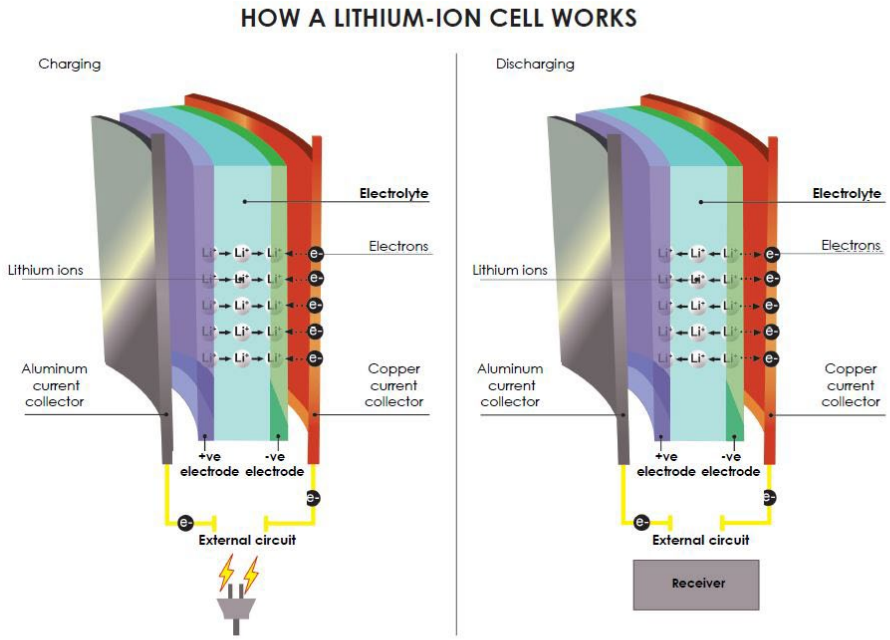


Image obtained from Energy Storage Association website, 2021.

The term "lithium polymer" (or more correctly, lithium-ion polymer) refers to a Li-ion design in which the electrodes are bonded together by a porous polymer matrix. Liquid electrolyte is infused into the porous matrix and becomes immobilized, allowing the electrode stacks to be assembled into foil "pouches" that provide geometric flexibility and improved energy density compared to cylindrical cells. However, such advantages are less significant as the cells are scaled up to larger capacities (Energy Storage Association Website, 2021). Additionally, lithium battery technologies have moved from chemistries using lithium-cadmium to lithium iron phosphates.

Note that there are also "lithium metal polymer" technologies, in which metallic lithium negative is implemented with a conductive polymer to make a solid-state battery system. Such technologies do not fall under the Li-ion umbrella and have not yet been successfully deployed in energy-storage applications (Energy Storage Association Website, 2021).

Lithium Iron Phosphates - is an inorganic compound with the formula $LiFePO_4$. It is a gray, red-grey, brown or black solid that is insoluble in water. Safety Data Sheet information for lithium iron phosphate shows that there is not applicable data associated with acute toxicity/chronic toxicity/long term toxicity. For the battery, chemical materials are stored in a sealed case, designed to withstand temperatures and pressures encountered during normal use. As a result, during normal use, there is no physical danger of ignition or explosion and chemical danger due to leakage of hazardous materials. However, if exposed to a fire, added mechanical shocks, decomposition, or added electric stress by miss-use, the gas release vent will be operated. The battery cell case will be breached and hazardous materials (lithium compounds or electrolytes) may be released to the environment. Moreover, if heated strongly by the surrounding fire, hydrogen fluorite gas may be emitted.

Lithium – is a soft, silvery-white metal and is highly reactive and flammable in its pure form. Most health studies associated with lithium have focused on the therapeutic uses of lithium carbonate and lithium citrate. The primary and most studied side effects lithium therapy produces are renal or kidney issues (nephrogenic diabetes insipidus, nephritis, and chronic progressive renal disease). The most frequent neurologic side effects are lethargy, fatigue, weakness, tremor and cognitive impairment. Endocrine glands such as the thyroid and parathyroid can also be affected. Although serious cardiovascular effects are rare, they do occur, the most common being changes in the EKG. Gastrointestinal side effects include nausea, vomiting, diarrhea and abdominal cramping. The most frequently observed hematological reaction is a benign leukocytosis (elevated white blood cell counts). USEPA recently recommended the following action/cleanup levels for lithium for a site which had a lithium battery fire:

> **Residential soil**: 160 ppm (based on the Provisional Peer Reviewed Toxicity Values (PPRTV) oral reference dose (RfD) value of 2E-3 mg/kg/day)
> **Water**: 40 ppb (also the PPRTV RfD)
> **Dust**: Sufficient dust collected with a Microvac sampler can measure Lithium concentration for comparison to the soil screening value.
> **Air**: 3 ug/m^3 (based on 0.3 mg/m3 as a No Observed Adverse Effect Level from the rabbit study, apply 100X Uncertainty Factors (10 for animal to human; 10 for human susceptibility).

Summary and ODH Assessment: Information to date does not indicate a public health burden from the use of lithium ion batteries operating under normal conditions. While more information is needed to understand the toxicity of lithium ion chemistries, there is not likely to be a completed exposure pathway to the general public if the battery systems are well maintained and monitored, and secured, such as by fencing around the installations. The greatest risk is if these systems catch fire releasing hydrogen fluoride gas which can combine with moisture to become hydrofluoric acid, a highly corrosive liquid and contact poison, and lithium metal. Release of these byproducts into the environment would be hazardous if exposure to skin were to occur and local and regional emergency response teams would need to be aware of the special precautions required for dealing with these types of fires.

Lead Acid Batteries

Lead batteries are the most extensively used rechargeable battery technology in the world. They have an unrivaled track record for reliability and safety, which together with a well-established worldwide supplier base, make them the dominant battery in terms of megawatt hours (MWh) of production. Lead battery chemistry is simple and robust. The active material is lead dioxide on the positive plates, and finely divided lead on the negative plates. Both of these materials react with sulfuric acid on discharge to form lead sulfate and water and the reverse reactions take place on recharge (Energy Storage Association Website, 2021).

Lead batteries for energy storage are made in a number of different types. They can be flooded which means that they require maintenance additions of water from time to time or valve-regulated lead-acid (VRLA) types which require no routine maintenance other than safety inspections. VRLA batteries are constructed such that hydrogen evolution is suppressed and oxygen is chemically recombined so that water loss is virtually eliminated. There are two technologies available: one uses an absorptive glass mat (AGM) as the separator and the other uses finely divided silica to gel the electrolyte. They both operate in a similar way but have different characteristics. Lead batteries also have different designs for particular applications and are mainly differentiated by the positive plate which may be tubular or a flat pasted plate (Energy Storage Association Website, 2021).

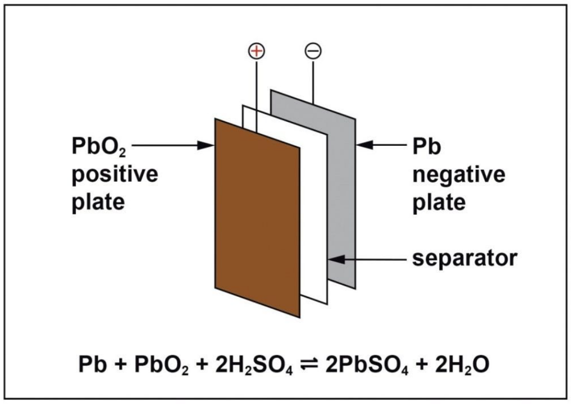


Image obtained from Energy Storage Association website, 2021.

Lead: Lead, in pure elemental form, is a toxic heavy metal. Lead can have numerous adverse health effects. The main target for lead toxicity is the nervous system. Long-term exposure of adults to lead at work has resulted in decreased performance in some tests that measure functions of the nervous system. Lead exposure may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure. Lead exposure may also cause anemia. At high levels of exposure, lead can severely damage the brain and can cause death. In pregnant women, exposure to lead may cause miscarriage or premature birth. High-level exposure in men can damage the organs responsible for sperm production.

Children are more vulnerable to lead poisoning than adults because their nervous systems are still developing. Children can be exposed to lead in their environment and before birth from lead in their mother's body. At lower levels of exposure, lead can decrease mental development, especially learning, intelligence, and behavior. Physical growth may also be decreased. A child who swallows large amounts of lead may develop anemia, severe stomachache, muscle weakness, and brain damage. Some effects of lead poisoning in a child may continue into adulthood (Agency for Toxic Substances and Disease Registry (ASTDR)). In the event of a leak or fire the following action/cleanup levels for lead are recommended:

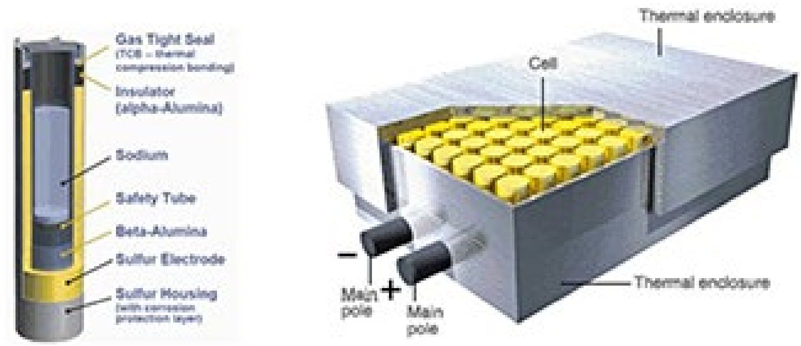
> **Residential soil**: 400 ppm (USEPA Regional Screening Level)
> **Water**: 15 ppb (USEPA MCL)
> **Dust**: Sufficient dust collected with a Microvac sampler can measure lead concentration for comparison to the soil screening value.
> **Air**: 0.15 ug/m^3 (USEPA Regional Screening Level)

Sulfuric Acid: Sulfuric acid is a clear, colorless, oily liquid that is very corrosive. It is also called sulphine acid, battery acid, and hydrogen sulfate (Safety Data Sheet (SDS) for sulfuric acid). Acute exposures to sulfuric acid can cause immediate burning of the eyes. Itchy, burning eyes can help to warn people of potentially hazardous exposure levels. The very young, the very old, and people with health problems are at an increased risk from the health effects of sulfuric acid exposure. The most common way for sulfuric acid to enter the body is through the respiratory system which can cause serious lung damage. Sulfuric acid can irritate the skin and cause chemical burns ranging from mild to severe, depending on the concentration of the sulfuric acid solution. Concentrated vapor or solution that contacts the skin may cause the victim to experience severe pain, redness of the skin, blisters and permanent scarring. Sulfuric acid or sulfuric acid vapor, even with short-term exposure, can irritate the eyes and cause burning, swelling, tearing of the eyes and/or blurred vision, and may cause blindness. Immediate burning in the mouth and throat occur when sulfuric acid is swallowed. Ingestion of concentrated solution can cause severe pain in the mouth, chest and abdomen, nausea and vomiting, or holes in the esophagus. Erosion of the teeth, inflammation of the mouth, narrowing of the stomach or esophagus, chronic bronchial irritation with cough, and/or chronic shortness of breath may occur with repeated or long-term exposure to sulfuric acid. Skin rashes may also occur with repeated exposures of dilute concentrations of sulfuric acid.

Summary and ODH Assessment: Information to date does not indicate a public health burden from the use of lead acid batteries operating under normal conditions. There is an abundance of information relating to the health effects of lead and sulfuric acid: however, the self-contained nature of these systems and the use of security measures such a fencing around large ground-mounted installations prevents exposure to the public and environment. ODH also recommends periodic maintenance and inspection of the battery storage area to ensure no leakage or damage has occurred. If leakage has occurred which has affected the local environment, the appropriate cleanup levels should be applied.

Sodium Sulfur (NaS) Batteries

The active materials in a NaS battery are molten sulfur as the positive electrode and molten sodium as the negative. The electrodes are separated by a solid ceramic, sodium alumina, which also serves as the electrolyte. This ceramic allows only positively charged sodium-ions to pass through. During discharge electrons are stripped off the sodium metal (one negatively charged electron for every sodium atom) leading to formation of the sodium-ions that then move through the electrolyte to the positive electrode compartment. The electrons that are stripped off the sodium metal move through the circuit and then back into the battery at the positive electrode, where they are taken up by the molten sulfur to form polysulfide. The positively charged sodium-ions moving into the positive electrode compartment balance the electron charge flow. During charge this process is reversed. The battery must be kept hot (typically > 300 ºC) to facilitate the process (i.e., independent heaters are part of the battery system). In general Na/S cells are highly efficient (typically 89%) (Energy Storage Association Website, 2021).



Sodium-Sulfur (NaS) Batteries

Image obtained from Energy Storage Association website, 2021.

Sodium: Sodium is a chemical element and is a soft, silvery-white, highly reactive metal. Sodium forms flammable hydrogen and caustic sodium hydroxide on contact with water. Ingestion and contact of metallic sodium with moisture on skin, eyes or mucous membranes can cause severe burns. Sodium spontaneously explodes in the presence of water due to the formation of hydrogen (highly explosive) and sodium hydroxide (which dissolves in the water, liberating more surface). However, sodium exposed to air and ignited or reaching autoignition (reported to occur when a molten pool of sodium reaches about 290 °C) displays a relatively mild fire (SDS for sodium).

Sulfur: Sulfur is a pale yellow, crystalline (sand-like) solid that is odorless when pure or may have a faint "rotten egg" odor. Powdered sulfur may be considered a nuisance dust causing eye irritations (characterized by burning, watery eyes, blurred vision, keratitis, and losses of corneal epithelium), skin irritations (Symptoms include reddening, itching, and inflammation), irritating to mucous membranes of respiratory tract when inhaled (causing coughing, sore throat, and shortness of breath) and gastrointestinal irritation, nausea, vomiting, and diarrhea if ingested. Skin sensitization has been observed in some people after repeated exposures. Chronic inhalation may cause bronchopulmonary disease which may be complicated by emphysema and bronchiectasis. No evidence for carcinogenicity according to National Toxicology Program (NTP), International Agency for Research on Cancer (IARC), National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), or the American Conference of Governmental Industrial Hygienists (ACGIH) (Right to Know for sulfur).

When molten (melting point 246^{o}F), sulfur is an amber color, flammable and can release poisonous gases such as Hydrogen Sulfide, Sulfur Dioxide and Sulfur Trioxide.

Summary and ODH Assessment: Information to date does not indicate a public health burden from the use of sodium sulfur batteries in the use of energy storage operating under normal conditions. While information is available to understand the toxicity of sodium and sulfur, there is not likely to be a completed exposure pathway to the general public given the fact that the batteries are fully enclosed within a thermal enclosure and, therefore, the elements are not likely to enter the environment. Security measures including fencing around large ground-mounted installations will help prevent contact from trespassers. The greatest danger associated with this technology is potential for poisonous gases and explosive gases associated with fires. Local and regional emergency response teams need to be aware of the special precautions required for dealing with these types of fires. ODH also recommends periodic maintenance and inspection of the battery storage area to ensure no leakage or damage has occurred.

Noise

Some components of a battery installation and operations produce noise. Battery systems are operationally silent, but the heating or cooling systems required by the systems may have a noise rating of less than 70 A-weighted decibels (dBA). The anticipated noise level at the project boundary should be less than 55 dB. This noise level is below the existing ambient noise level of residential neighborhoods. The sound level will drop further as a function of distance from the project boundary and be less than 40 dB (the sound of water on a window) at 100 ft) away.

Some noise will occur during the construction phase of a battery storage infrastructure and installation. This noise is expected to be typical construction noise (i.e. heavy machinery, land grading, etc.) and is temporary and unavoidable. The noise generated during the construction is expected to be much louder than the noise generated during its typical operation (source: San Diego County).

Additionally, there may be some amount of noise generated by the upkeep and maintenance of battery systems, but these are expected to be standard community levels of sound (i.e., lawnmowers, string trimmers or “weed whackers”, etc.) (source: National Renewable Energy Laboratory (NREL)).

Summary and ODH Assessment: Information to date does not indicate a public health burden from noise generated by the typical operation and maintenance of a battery system. While some noise is anticipated and unavoidable, it is not expected to create off-site health issues.

The inclusion of setbacks from residential areas should help ensure any noise generated by the battery systems has reached ambient levels by the time it nears a residential structure.

ODH recommends that, during construction, operation, and maintenance, state and local construction noise and noise pollution ordinances should be adhered to. ODH also recommends periodic maintenance and inspection of the battery storage area to ensure no leakage or damage has occurred.

Battery System End of Life Disposal and Storage

An average battery system will last for 10 to 20 years after initial installation, after which it will be decommissioned for recycling, or landfill disposal.

Lead batteries are widely recycled. Thanks to its long-established collection and recycling scheme, almost all used lead batteries are collected at end-of-life for recycling – the highest of all battery technologies. Lead batteries exemplify the fundamental principles of eco-design: they are designed to be recycled at end-of-life with more than 90% of their material being recovered. The average lead battery made today contains more than 80% recycled materials, and almost all of the lead recovered in the recycling process is used to make new lead batteries.

Lithium ion batteries are currently recycled at a rate of 5% with the remainder being sent to landfills for disposal. The rate of the percent recycled should improve during the next five years with the investment and planning for lithium ion battery specific recycling centers, and the U.S. Department of Energy's investments into research associated with recycling and battery collection.

Sodium sulfur batteries contain reactive and corrosive materials, but not toxic ones. By treatment of the battery waste, the reactivity problems can be removed. The major difficulty in recycling this chemistry is that most of the constituents have low value or are difficult to recover in a form that could be used in a high-value application. Pilot study research on recycling sodium sulfur batteries has been conducted and is promising if sodium sulfur battery use increases in the future.

Summary and ODH Assessment: In order to prevent public health risks, ODH recommends that battery end of life disposal and storage plans be considered during the application and review process for new energy storage projects, and again during the decommissioning of energy storage units.

Electromagnetic Fields

Batteries themselves do not produce electromagnetic fields (EMFs). The wires connecting the batteries to the source of power used in charging the batteries, and the wires connecting the batteries to the electric grid will produce EMFs during the discharging of the batteries. The science around EMF and possible health concerns has been extensively researched, with tens of thousands of scientific studies published on the issue and many government and medical agencies weighing in on the issue. The weight of scientific evidence does not support a causal link between EMF and health issues at the levels typically encountered by most people (Knopper et al., 2014). Additional information concerning EMFs can be reviewed in the Ohio Department of Health Summary Document.

Summary and ODH Assessment: There is no significant body of peer-reviewed, scientific evidence that clearly demonstrates there is any link between adverse physical health effects and exposures to electromagnetic fields (EMF).

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