M-i1 Lithium-Ion Batteries: Fires, Chemicals, Health, and Cleanup

March 24, 2025 8 am- 10 am
Karen Riveles and Ance Trapse
Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

27th California Unified Program
Annual Training Conference
March 24-27, 2025

Pre-Class Videos

1. E-scooter on charge bursts into flames before a huge explosion
2. Caught on camera: Lithium-Ion battery sparks fire in LA county home
3. Exploding hoverboard nearly sets family's house on fire

1

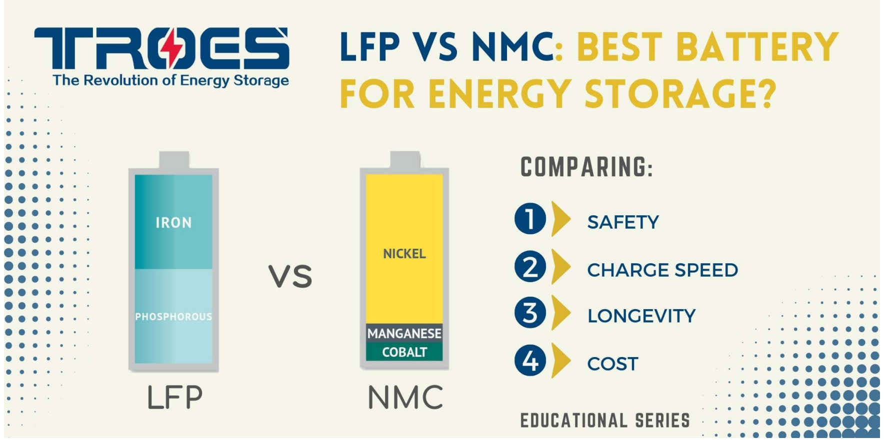
2

3

Overview

- What are Lithium-Ion Batteries (LIBs) and how do they work?
- What is thermal runaway?
- What types of products contain LIBs?
- Examples of incidents involving LIBs in California and beyond
- Injuries and hospitalizations from LIBs
- Chamber studies on emissions from LIBs
  - Chemicals emitted from LIBs
  - Exposure considerations
  - Health and safety information related to selected chemicals of concern
- Hazards and safety guidelines
- Emergency response and cleanup after an LIB fire
  - Testing: Air, soil, surface water, drinking water, biota, runoff

What are Lithium-Ion Batteries (LIBs) and how do they work?



https://troescorp.com/lfp-vs-nmc-best-battery-for-energy-storage/

What are Lithium-Ion Batteries (LIBs)?

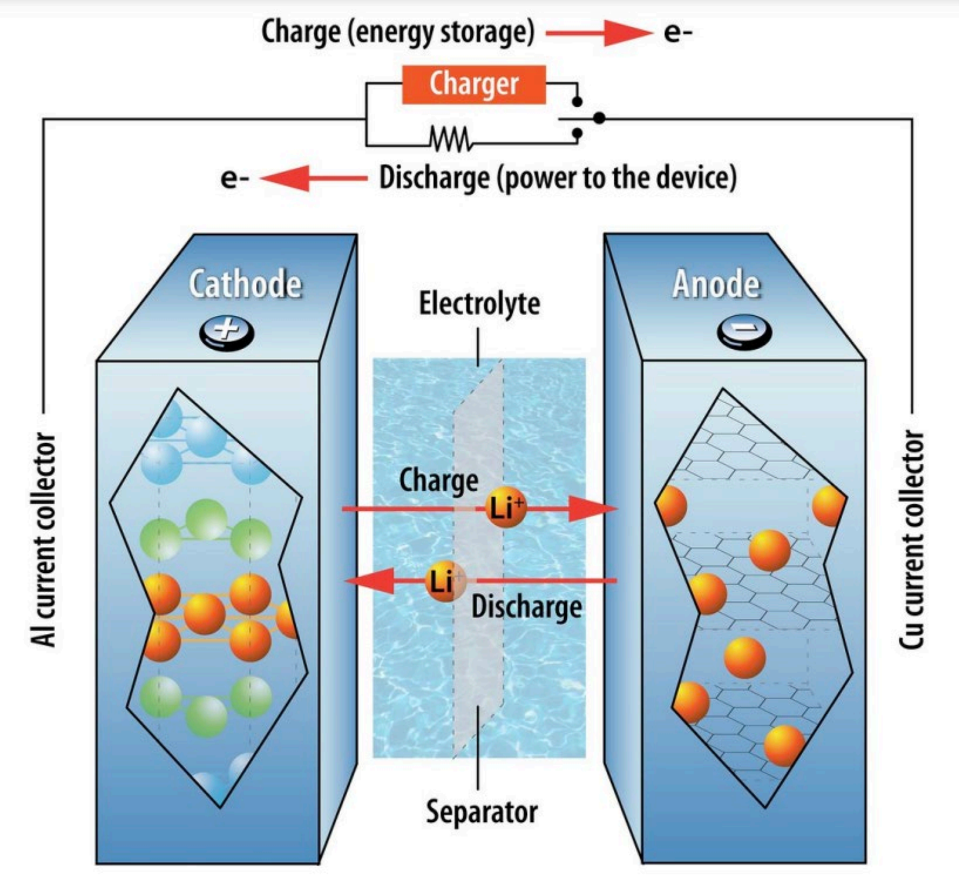


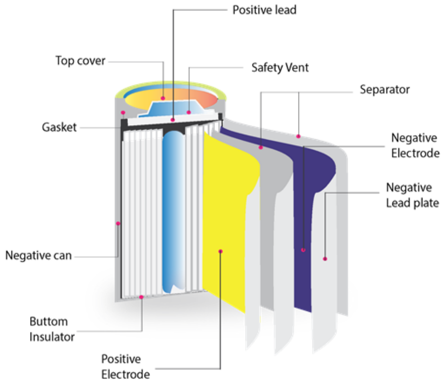
Figure 1: Diagram of an LIB.

"How a lithium-ion battery works" by Argonne National Laboratory licensed with CC BY-NC-SA 2.0. To view a copy of

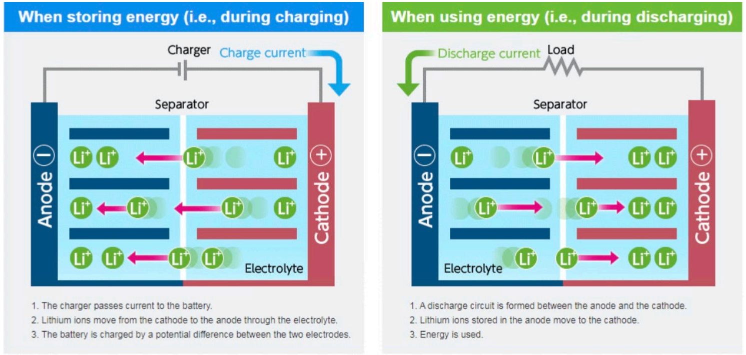
- Main components: **anode**, **cathode**, and a **separator**
- Anode = negative end of the battery cell, composed of graphite embedded with lithium compound
- Cathode = positive end, usually made of cobalt oxide
- Separator = liquid electrolyte - allows for lithium ions to pass from one side to another

How do Lithium-ion Batteries Work?

- The LIB **core**:
  - Comprised of alternating layers of <u>anode</u> and <u>cathode</u> metal
  - Separated by a porous film containing a liquid electrolyte
  - Composed of lithium salts dissolved in an organic solvent
- The core is inserted into a metal cylinder
  - It is sealed to prevent the electrolyte from evaporating and being released



https://www.batterypowertips.com/difference-between-lithium-ion-lithium-polymer-batteries-faq/



1. The charger passes current to the battery.
2. Lithium ions move from the cathode to the anode through the electrolyte.
3. The battery is charged by a potential difference between the two electrodes.

1. A discharge circuit is formed between the anode and the cathode.
2. Lithium ions stored in the anode move to the cathode.
3. Energy is used.

https://evreporter.com/understanding-lithium-ion-batteries-a-long-read/

Types of Batteries

Lithium nickel manganese cobalt oxide (NMC)

https://reads.alibaba.com/everything-you-need-to-know-about-selecting-nmc-batteries/

Lithium iron phosphate (LFP)

https://www.litime.com/collections/12v-batteries/products/litime-12v-100ah-lithium-lifepo4-battery?srsltid=AfmBOorpCy0vRLybWt5zj9vEHYyF7qNefnhDUMgIW7z2PDd_klEigbUJTEc

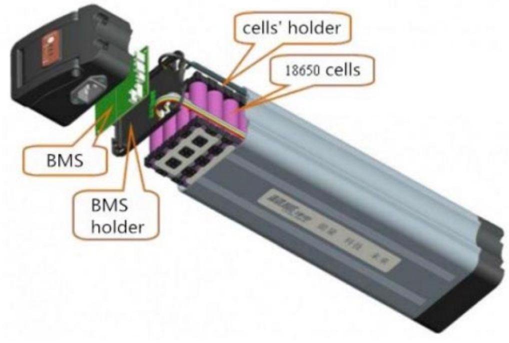
Lithium titanate oxide (LTO)

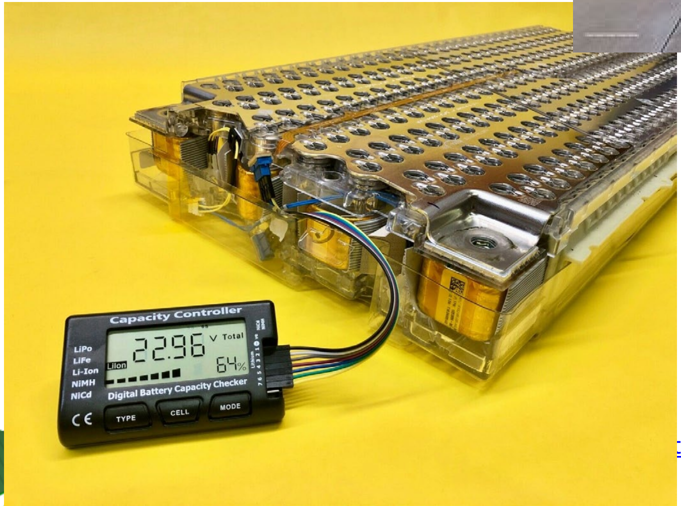
https://www.ecolithiumbattery.com/product/40ah-lto-battery/

Other types: Lithium Cobalt Oxide (LCO), Lithium Nickel Cobalt Aluminum Oxide (NCA), Lithium Manganese Oxide (LMO)

Different Batteries

Battery Packs:





eway Energy Camino

https://www.dhses

What is thermal runaway?

What is Thermal Runaway?

Thermal runaway can occur after a LIB is damaged (thermal, mechanical, electrical)

Internal temperature of the battery increases uncontrollably (exothermic reactions) between the lithium electrolyte and electrodes

Heated lithium vaporizes and decomposes releasing gaseous lithium **(and a whole bunch of other chemicals!)**

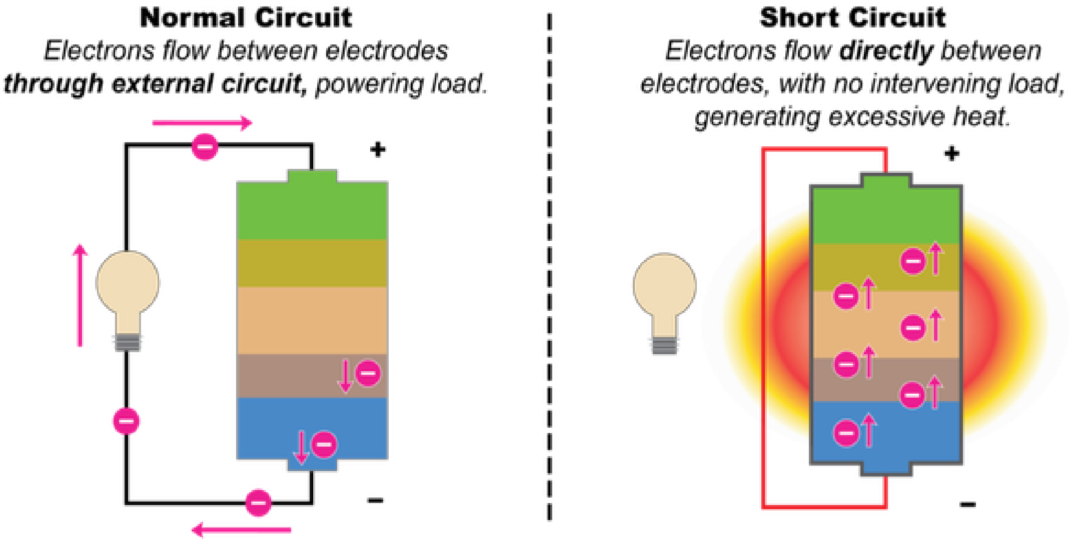
The increased internal pressure of the battery can ignite electrolyte components causing explosion or fire

Why do they explode?

- Overheating of batteries may result in **exothermal reactions** and lead to thermal runaway with excessive amounts of heat, gas, & emissions

- Both energetic and non-energetic failures of LIB cells and batteries can occur:
  - Poor cell design
  - Cell manufacturing flaws
  - External abuse of cells
  - Poor battery pack design
  - Poor charger or system design

- **Safety and Health Hazard**: Ignition of the cell due to thermal runaway and its accompanying gaseous emissions
- **Release of harmful gases and fire**



https://www.lifepo4battery-factory.com/4-point-tell-you-what-is-lifepo4-battery/

Why do they re-ignite?

Fire Extinguishers do not work on LIB fires

- LIBs can continue to generate heat with no visible sign of fire
  - They can enter a self-heating state --> results in release of gas, cause fire, or explode

- While a vehicle is charging, cells in the battery at a high state of charge (SOC) can cause an internal short circuit

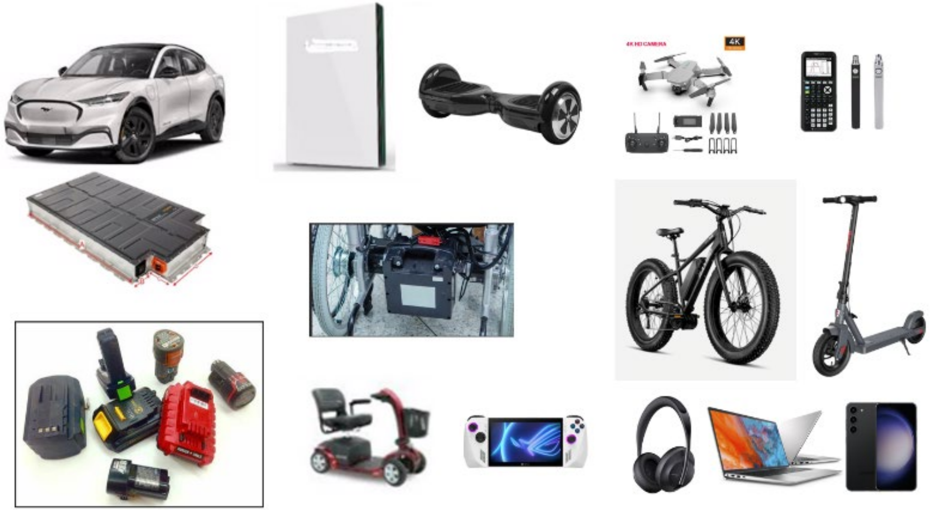
A 2019 Chevrolet Bolt EV caught fire at a home in Cherokee County, Georgia on Sept. 13, 2021, according to the local fire department.

Cherokee County Fire Department

https://www.cnbc.com/2023/04/20/f-150-lightning-fire-footage-growing-ev-risk.html

https://www.nyc.gov/assets/fdny/downloads/pdf/codes/dangers-of-lithium-ion-batteries.pdf

What types of products contain Lithium-Ion Batteries (LIBs)?



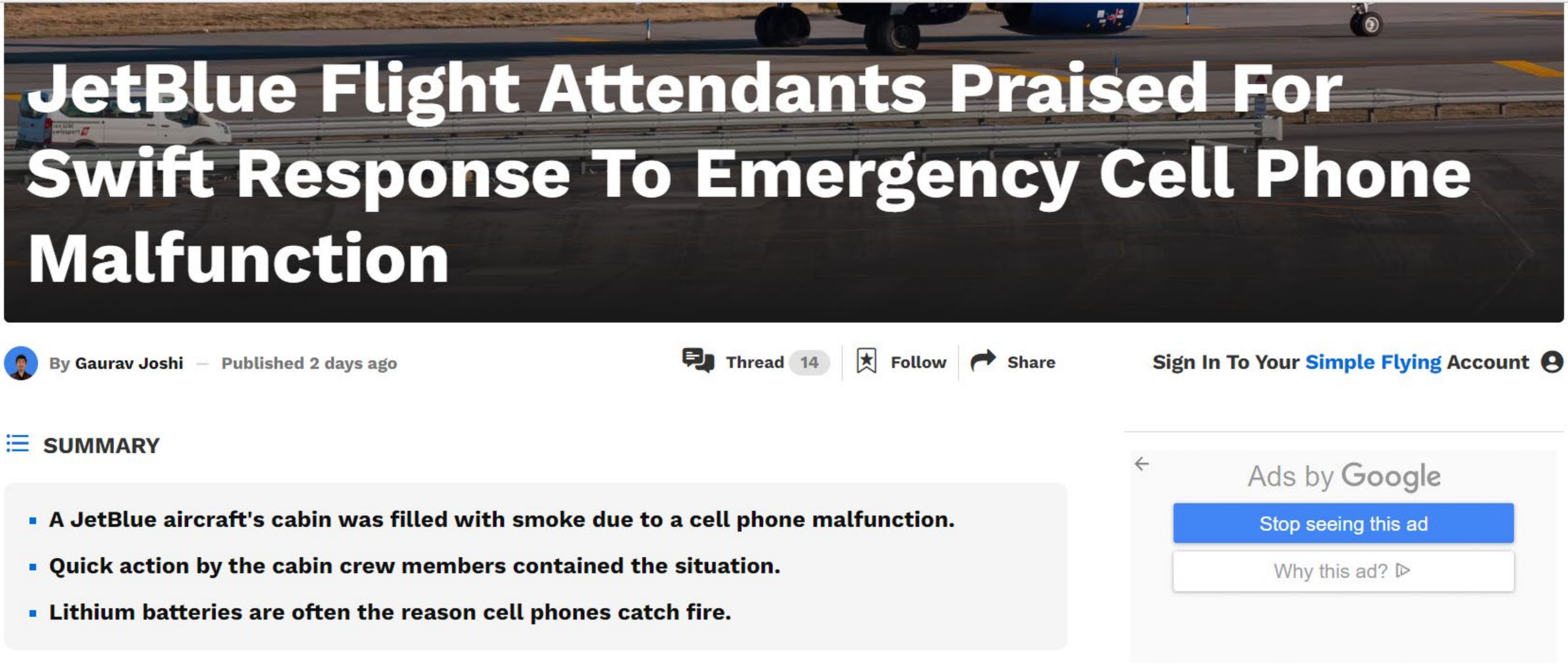
Products with Lithium-Ion Batteries

hone/samsung-galaxy-s23 https://www.walmart.com/ip/Drone-Clearance-Sales-4k-Profesional-HD-Dual-Camera-WiFi-4K-Real-time-Transmission-FPV-Drones-Collapsible-Quadcopter-Toy-Gifts-Adults-Kids/168949342 https://www.bestbuy.com/site/asus-rog-ally-7-120hz-fhd-1080p-gaming-handheld-amd-ryzen-z1-processor-512gb-white/6543664.p?skuId=6543664&extStoreId=133&utm_source=feed&ref=212&loc=20103022946&gad_source=1&gclid=Cj0KCQiAqsitBhDlARIsAGMR1RjKcHeVQuL_cesYgYcMh2yDJdFEHwDeiO8KY8p91aKB0lDwHZZk3LMaAnAWEALw_wcB&gclsrc=aw.ds

tops

urs-runtime- https://lighterusa.com/products/ooze-lithium-ion-battery https://www.amazon.com/Texas-Instruments-Frustration-Free-84PLCE https://razor.com/products/electric-scooters/c25-electric-scooter/

Examples of incidents involving LIBs in California and beyond



JetBlue Flight Attendants Praised For Swift Response To Emergency Cell Phone Malfunction

By **Gaurav Joshi** — Published 2 days ago

SUMMARY

- A JetBlue aircraft's cabin was filled with smoke due to a cell phone malfunction.
- Quick action by the cabin crew members contained the situation.
- Lithium batteries are often the reason cell phones catch fire.

Video showing LIB fires from consumer products

Examples of Lithium Battery Fires - YouTube

Electric Truck Fires

CARSON, Calif. (KABC) -- Days after an electric truck ran into a cargo train in Carson and caught fire, the vehicle is still smoldering.

https://abc7.com/electric-truck-crash-carson-los-angeles-county-volvo/13720236/

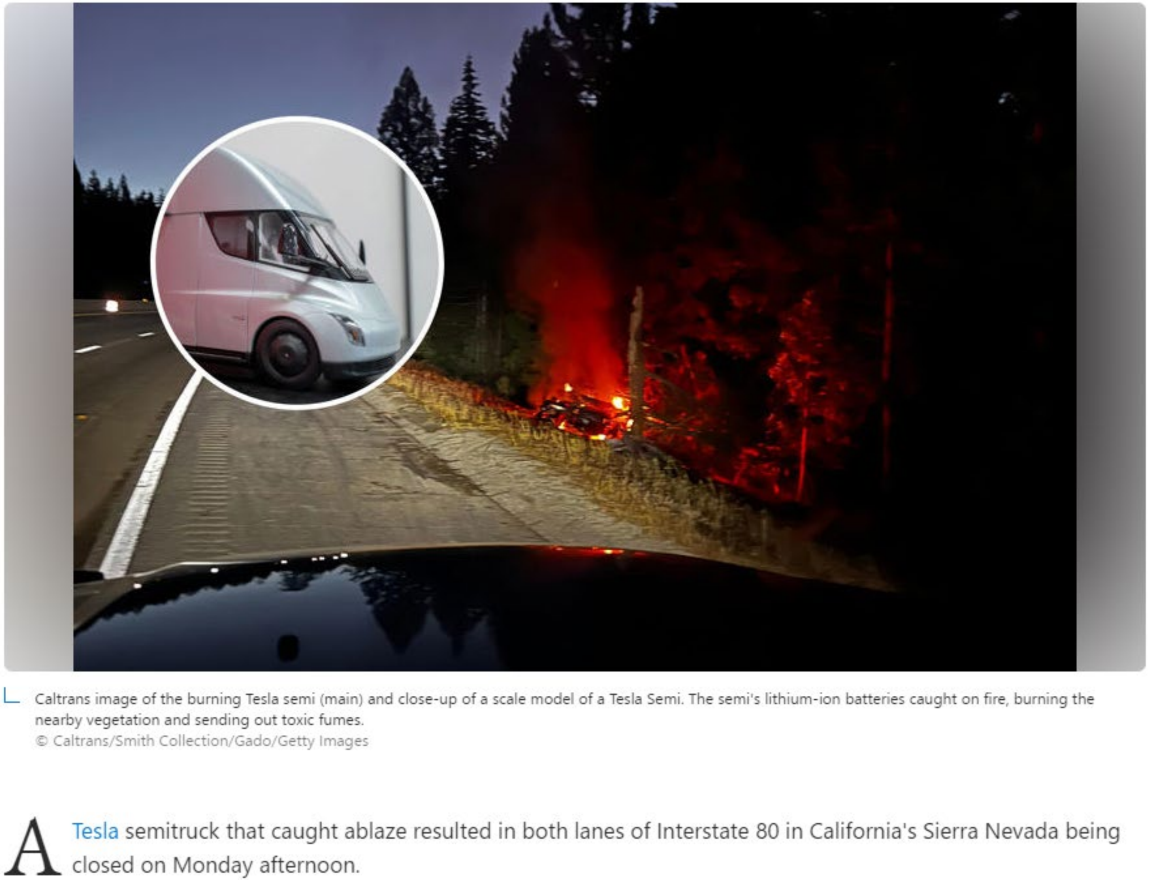
Ford F-150 Lightning Fire (2023)

An electric Ford F-150 Lightning caught fire on Feb. 4, 2023 due to a battery issue traced back to one of the automaker's suppliers. The blaze spread to two other electric pickups in a holding lot of Ford's in Dearborn, Michigan.

Dearborn Police Department

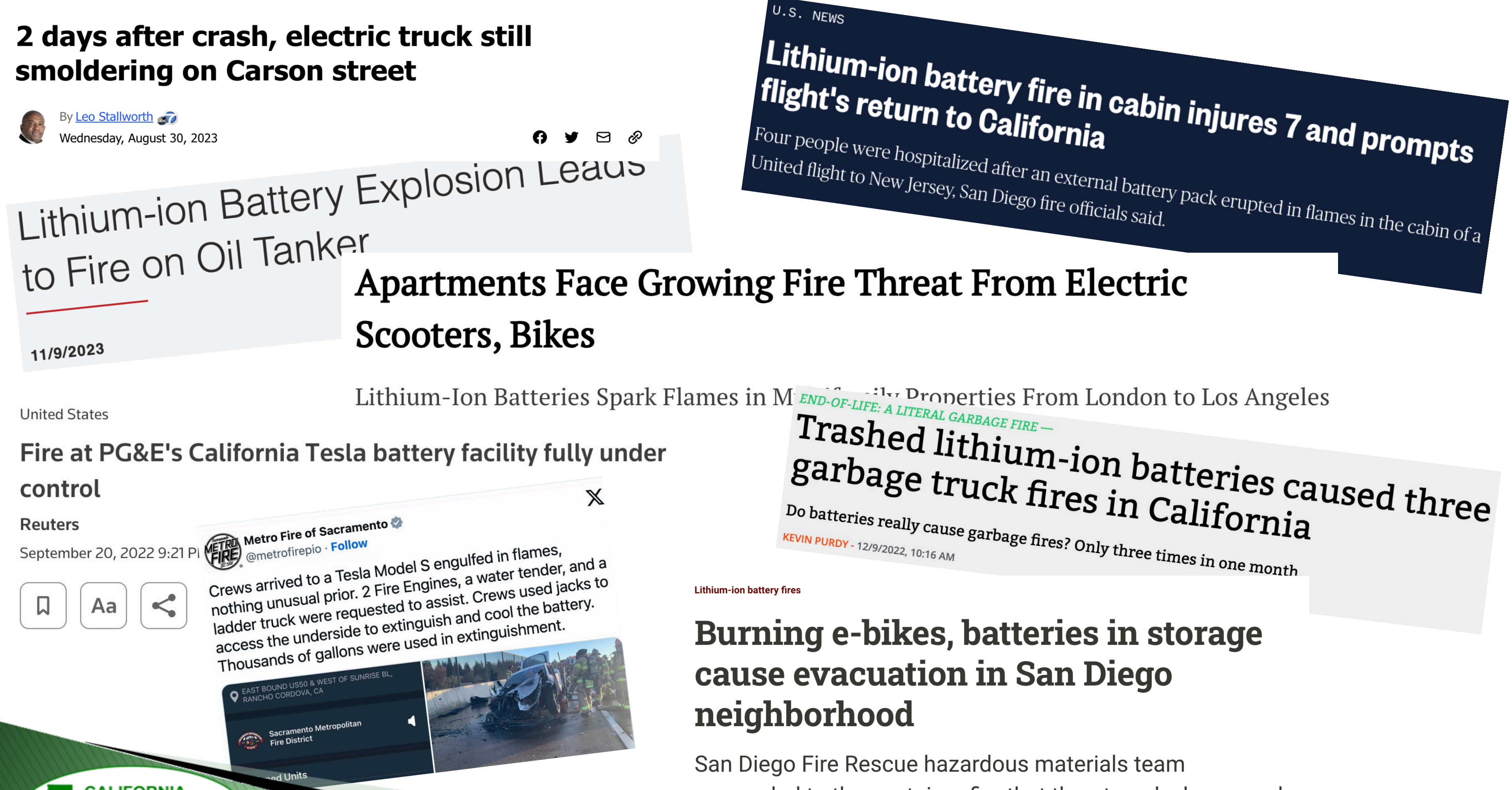
https://www.cnbc.com/2023/04/20/f-150-lightning-fire-footage-growing-ev-risk.html

Toxic Fumes Spewing From Tesla Semitruck Forces California Freeway Closure (msn.com)



Caltrans image of the burning Tesla semi (main) and close-up of a scale model of a Tesla Semi. The semi's lithium-ion batteries caught on fire, burning the nearby vegetation and sending out toxic fumes.
© Caltrans/Smith Collection/Gado/Getty Images

A Tesla semitruck that caught ablaze resulted in both lanes of Interstate 80 in California's Sierra Nevada being closed on Monday afternoon.



2 days after crash, electric truck still smoldering on Carson street

By Leo Stallworth
Wednesday, August 30, 2023

U.S. NEWS

Lithium-ion battery fire in cabin injures 7 and prompts flight's return to California

Four people were hospitalized after an external battery pack erupted in flames in the cabin of a United flight to New Jersey, San Diego fire officials said.

Lithium-ion Battery Explosion Leads to Fire on Oil Tanker

11/9/2023

Apartments Face Growing Fire Threat From Electric Scooters, Bikes

Lithium-Ion Batteries Spark Flames in M

Properties From London to Los Angeles

United States

Fire at PG&E's California Tesla battery facility fully under control

Reuters
September 20, 2022 9:21 PI

END-OF-LIFE: A LITERAL GARBAGE FIRE —

Trashed lithium-ion batteries caused three garbage truck fires in California

Do batteries really cause garbage fires? Only three times in one month

KEVIN PURDY - 12/9/2022, 10:16 AM

Metro Fire of Sacramento
@metrofirepio · Follow

Crews arrived to a Tesla Model S engulfed in flames, nothing unusual prior. 2 Fire Engines, a water tender, and a ladder truck were requested to assist. Crews used jacks to access the underside to extinguish and cool the battery. Thousands of gallons were used in extinguishment.

Lithium-ion battery fires

Burning e-bikes, batteries in storage cause evacuation in San Diego neighborhood

San Diego Fire Rescue hazardous materials team responded to the container fire that threatened a home and high-rise

//www.firerescue1.com/lithium-ion-battery-fires/articles/burning-e-
rage-cause-evacuation-in-san-diego-neighborhood-

/NR20231109.aspx

lvo/13720236/

https://www.reuters.com/world/us/fire-tesla-powered-pge-facility-shuts-down-part-highway-1-california-2022-09-20/

https://www.cnbc.com/2023/04/20/f-150-lightning-fire-footage-growing-ev-risk.html

https://www.nbcnews.com/news/us-news/battery-fire-cabin-injures-7-prompts-flights-return-southern-californi-rcna69596

CALIFORNIA CUPA FORUM

The Ongoing Risk of LIB Fires: Notable incidents – United States

California

- Templeton 1/30/25: Debris fire at **recycling center** caused by trashed LIBs
- Ojai 1/25/25: **Electric vehicle** fire forces evacuations

New York City (2025)

- LIB starts fire at Walkill apartment, forcing 75 people to evacuate
- Drone video of village block destroyed by fire; Finger Lakes community rallies to help victims – putting 60 people out of work
- NYC Fire Department issued stricter e-bike storage and charging regulations

Connecticut

- **Snow blower** destroyed by lithium battery blaze – caught fire while being used to clear snow after a storm

Oregon

- Three **garbage truck fires** occurred within a week in Clackamas County

Source: The Ongoing Risk of Lithium-Ion Battery Fires: A Continuing Global Series

The Ongoing Risk of LIB Fires

Notable incidents – Europe & UK

London

- **E-Scooter & E-Bike** Fires (2025)
  - Lithium battery fire damages shop and apartments in Stratford – fire broke out in **residential shop** with flats above

New Zealand & Belgium

- Ashburton, New Zealand: January 2025 – fire broke out in a home originating in the bedroom containing LIBs
- Belgium (2025): Brussels flat declared 'uninhabitable' after **scooter** explosion

The Ongoing Risk of Lithium-Ion Battery Fires: A Continuing Global Series

The Ongoing Risk of LIB Fires

- **India & Ireland** – Warehouse and Factory Fires (2025)
  - India (January 2025): **Scooter** battery explodes, 28 e-bikes gutted in Bengaluru's Rajajinagar showroom fire
  - Ireland (January 2025): Fire that started in a **shipping container** holding LIBs at Xerotech in Claregalway Corporate Park burned for 3 days
- **Australia** – 2025
  - Victoria: A Tesla Megapack **energy storage site** in Victoria caught fire, burning for over three days
  - Sydney: **E-bike** charging near the front door trapping resident inside
  - Melbourne: **Warehouse** fire fueled by 3,000 LIBs, fire spread to adjacent warehouse

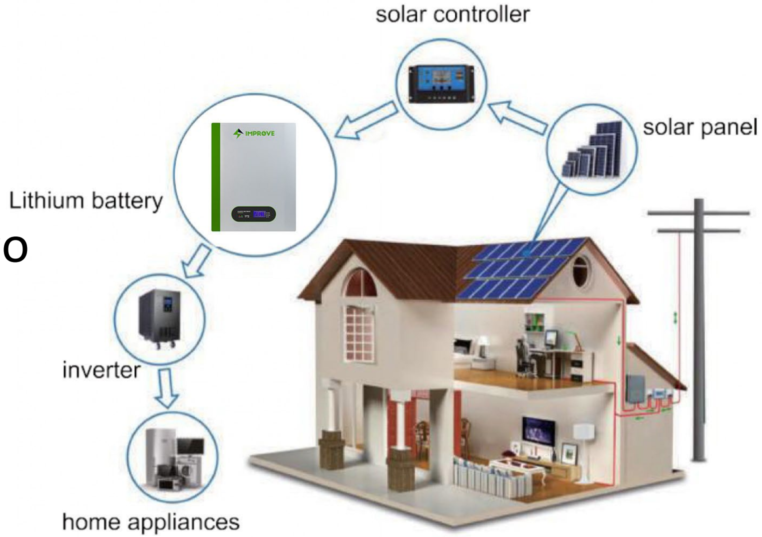
The Ongoing Risk of Lithium-Ion Battery Fires: A Continuing Global Series

Large-Scale Battery Energy Storage Systems (BESS)

LS Power's 250 MW Gateway project in San Diego

Saticoy Battery Storage Project

Home energy storage systems:

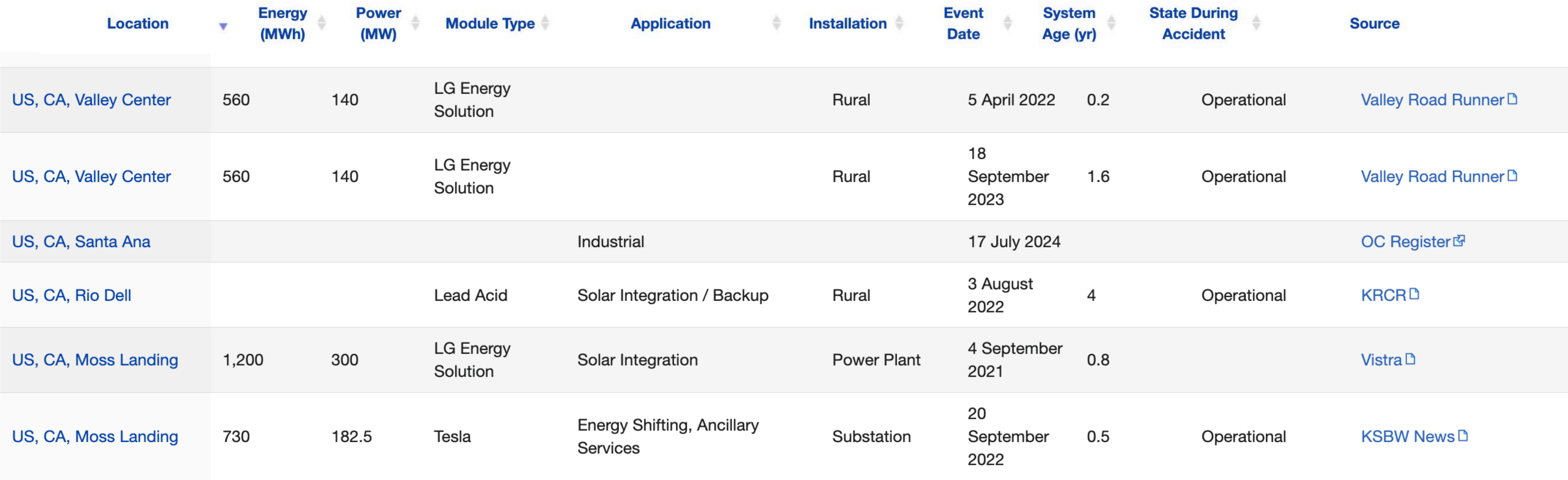


https://keyt.com/lifestyle/2021/06/29/area-near-oxnard-now-home-to-one-of-the-largest-energy-storage-sites-in-u-s/

https://www.improvecn.com/articles/improve-home-energy-storage-system

https://www.pv-magazine.com/2020/08/20/worlds-largest-battery-storage-system-now-operational/

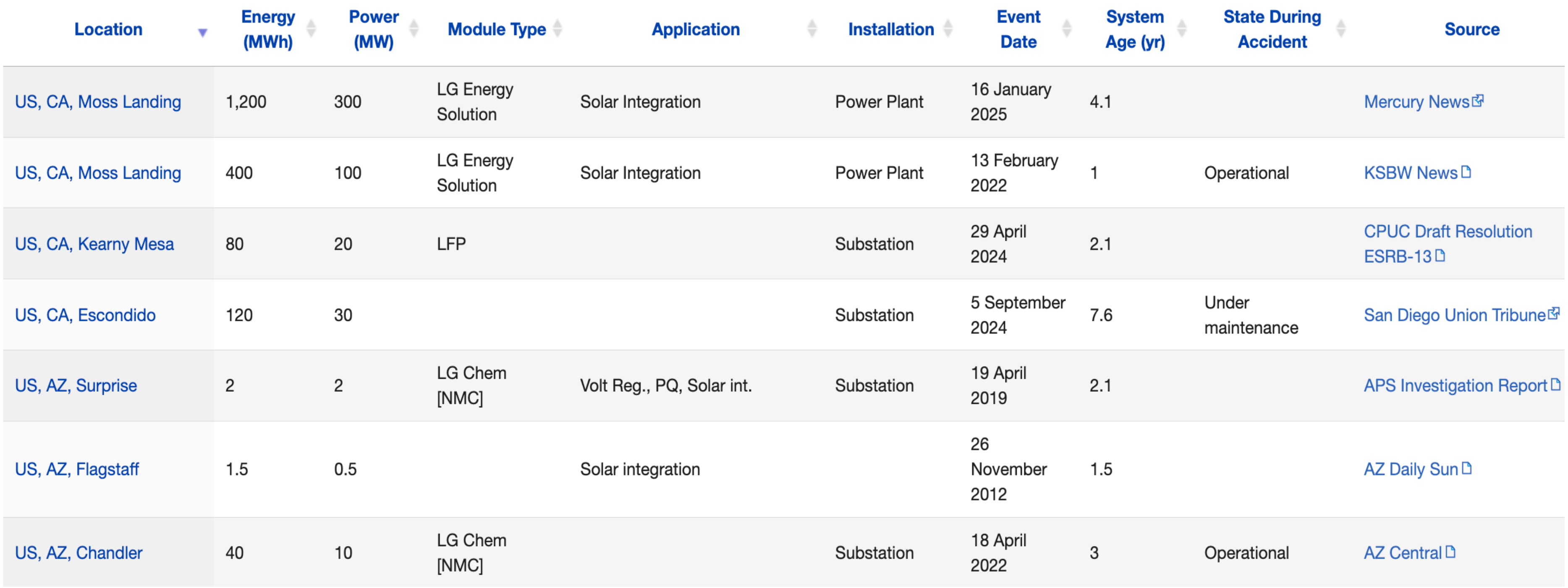
Incidents involving Battery Energy Storage Systems (BESS)



Location	Energy (MWh)	Power (MW)	Module Type	Application	Installation	Event Date	System Age (yr)	State During Accident	Source
US, CA, Valley Center	560	140	LG Energy Solution		Rural	5 April 2022	0.2	Operational	Valley Road Runner
US, CA, Valley Center	560	140	LG Energy Solution		Rural	18 September 2023	1.6	Operational	Valley Road Runner
US, CA, Santa Ana				Industrial		17 July 2024			OC Register
US, CA, Rio Dell			Lead Acid	Solar Integration / Backup	Rural	3 August 2022	4	Operational	KRCR
US, CA, Moss Landing	1,200	300	LG Energy Solution	Solar Integration	Power Plant	4 September 2021	0.8		Vistra
US, CA, Moss Landing	730	182.5	Tesla	Energy Shifting, Ancillary Services	Substation	20 September 2022	0.5	Operational	KSBW News

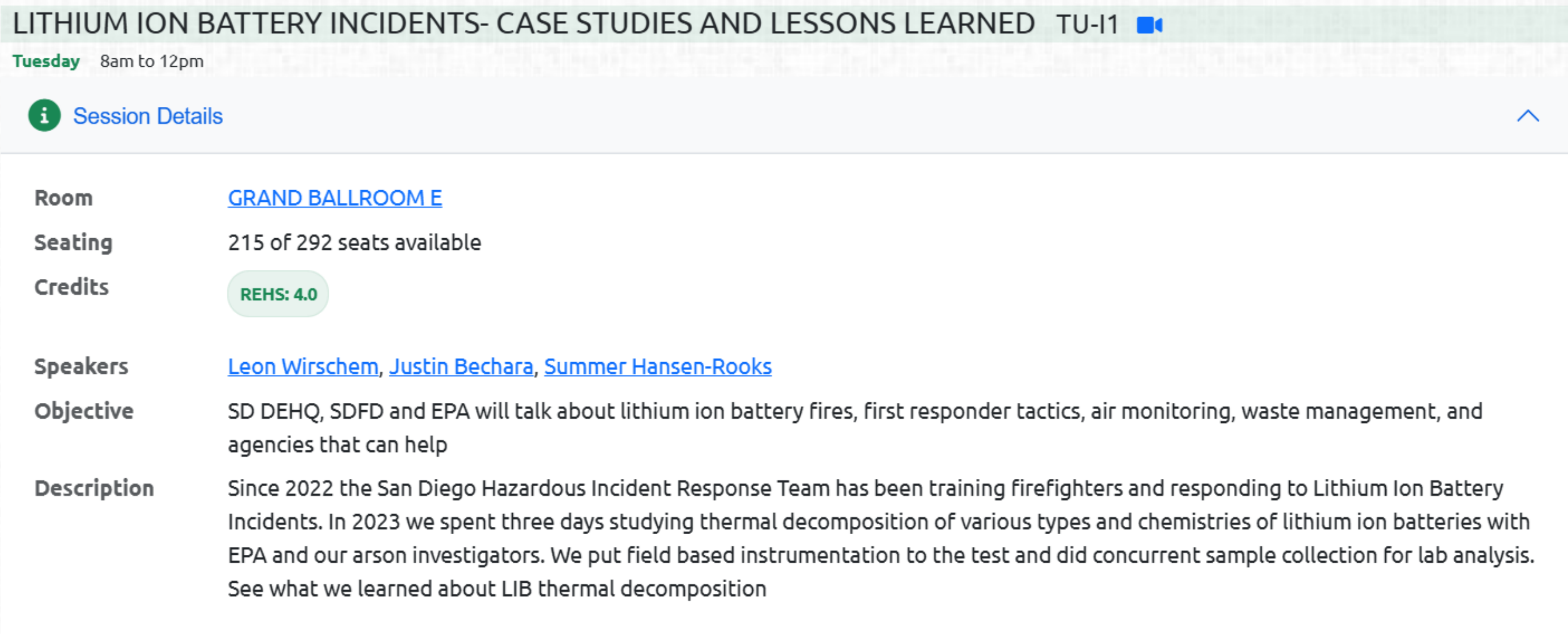
https://storagewiki.epri.com/index.php/BESS_Failure_Incident_Database

Incidents involving Battery Energy Storage Systems (BESS)



Location	Energy (MWh)	Power (MW)	Module Type	Application	Installation	Event Date	System Age (yr)	State During Accident	Source
US, CA, Moss Landing	1,200	300	LG Energy Solution	Solar Integration	Power Plant	16 January 2025	4.1		Mercury News
US, CA, Moss Landing	400	100	LG Energy Solution	Solar Integration	Power Plant	13 February 2022	1	Operational	KSBW News
US, CA, Kearny Mesa	80	20	LFP		Substation	29 April 2024	2.1		CPUC Draft Resolution ESRB-13
US, CA, Escondido	120	30			Substation	5 September 2024	7.6	Under maintenance	San Diego Union Tribune
US, AZ, Surprise	2	2	LG Chem [NMC]	Volt Reg., PQ, Solar int.	Substation	19 April 2019	2.1		APS Investigation Report
US, AZ, Flagstaff	1.5	0.5		Solar integration		26 November 2012	1.5		AZ Daily Sun
US, AZ, Chandler	40	10	LG Chem [NMC]		Substation	18 April 2022	3	Operational	AZ Central

https://storagewiki.epri.com/index.php/BESS_Failure_Incident_Database



LITHIUM ION BATTERY INCIDENTS- CASE STUDIES AND LESSONS LEARNED TU-I1

Tuesday 8am to 12pm

Session Details

Room	GRAND BALLROOM E
Seating	215 of 292 seats available
Credits	REHS: 4.0
Speakers	Leon Wirschem, Justin Bechara, Summer Hansen-Rooks
Objective	SD DEHQ, SDFD and EPA will talk about lithium ion battery fires, first responder tactics, air monitoring, waste management, and agencies that can help
Description	Since 2022 the San Diego Hazardous Incident Response Team has been training firefighters and responding to Lithium Ion Battery Incidents. In 2023 we spent three days studying thermal decomposition of various types and chemistries of lithium ion batteries with EPA and our arson investigators. We put field based instrumentation to the test and did concurrent sample collection for lab analysis. See what we learned about LIB thermal decomposition

Lithium-Ion Battery Fires in Electric Vehicles – Safety Risks to Emergency Responders by National Transportation Safety Board (NTSB) Video

https://www.youtube.com/watch?v=J6eS6JzBn0k

Injuries & Hospitalizations from LIBs

Related case studies and incident reports

Warning

- Graphic images of injuries included in this presentation may be unpleasant for some people

Injuries and Hospitalizations from LIB Fires in the News

New York City:

- As of Feb 2023, at least 30 fires, 40 injuries, and 2 deaths were caused by LIBs

https://www.facilities.cuimc.columbia.edu/news/lithium-ion-battery-safety

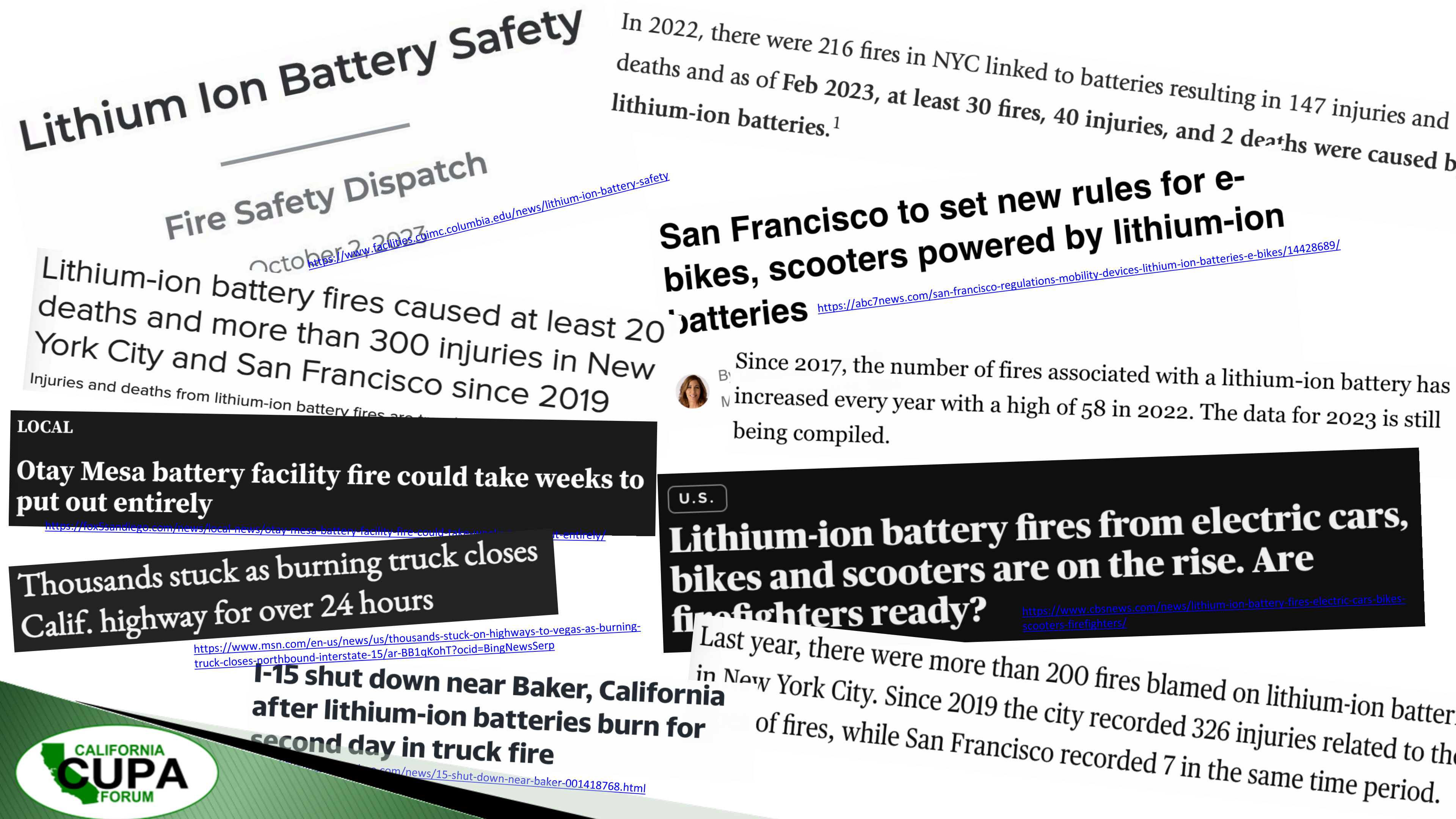
California:

- Per San Francisco's Fire Marshal, since 2017, number of LIB fires increased every year with a high of 58 in 2022.
- Within a 6-year period, one person died and eight individuals were injured.

https://abc7news.com/san-francisco-regulations-mobility-devices-lithium-ion-batteries-e-bikes/14428689/

New York & San Francisco:

- Per CBS News, as of 2019, the city recorded 326 injuries related to LIB fires and 7 in San Francisco. recorded 7 in the same period.
- LIB fires caused at least 20 deaths and more than 300 injuries in New York City and San Francisco since 2019. https://www.cbsnews.com/news/lithium-ion-battery-fires-electric-cars-bikes-scooters-firefighters/



Lithium Ion Battery Safety

Fire Safety Dispatch

October 2, 2023

https://www.facilities.cuimc.columbia.edu/news/lithium-ion-battery-safety

In 2022, there were 216 fires in NYC linked to batteries resulting in 147 injuries and deaths and as of Feb 2023, at least 30 fires, 40 injuries, and 2 deaths were caused b lithium-ion batteries.[1]

San Francisco to set new rules for e-bikes, scooters powered by lithium-ion batteries

https://abc7news.com/san-francisco-regulations-mobility-devices-lithium-ion-batteries-e-bikes/14428689/

Lithium-ion battery fires caused at least 20 deaths and more than 300 injuries in New York City and San Francisco since 2019

Injuries and deaths from lithium-ion battery fires are

Since 2017, the number of fires associated with a lithium-ion battery has increased every year with a high of 58 in 2022. The data for 2023 is still being compiled.

LOCAL

Otay Mesa battery facility fire could take weeks to put out entirely

https://fox5sandiego.com/news/local-news/otay-mesa-battery-facility-fire-could-take- t-entirely/

Thousands stuck as burning truck closes Calif. highway for over 24 hours

https://www.msn.com/en-us/news/us/thousands-stuck-on-highways-to-vegas-as-burning-truck-closes-northbound-interstate-15/ar-BB1qKohT?ocid=BingNewsSerp

U.S.

Lithium-ion battery fires from electric cars, bikes and scooters are on the rise. Are firefighters ready?

https://www.cbsnews.com/news/lithium-ion-battery-fires-electric-cars-bikes-scooters-firefighters/

I-15 shut down near Baker, California after lithium-ion batteries burn for second day in truck fire

com/news/15-shut-down-near-baker-001418768.html

Last year, there were more than 200 fires blamed on lithium-ion batter in New York City. Since 2019 the city recorded 326 injuries related to th of fires, while San Francisco recorded 7 in the same time period.

CALIFORNIA CUPA FORUM

LIB Fire Injuries from electric cars, bikes, & scooters

June 2023

Injuries and deaths from Lithium-ion battery fires:

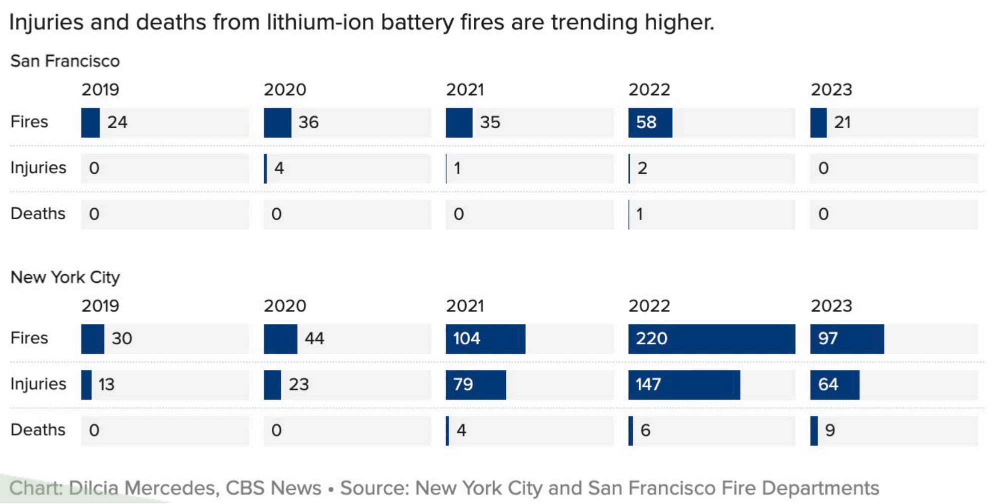
4 people were killed & 2 injured from LIB in an e-bike shop in New York

2019 -2023

Since 2019, New York has reported 326 injures related to LIB fires

San Francisco & New York have responded to at least 669 incidents combined

https://www.cbsnews.com/news/lithium-ion-battery-fires-electric-cars-bikes-scooters-firefighters/



Injuries and deaths from lithium-ion battery fires are trending higher.

San Francisco

	2019	2020	2021	2022	2023
Fires	24	36	35	58	21
Injuries	0	4	1	2	0
Deaths	0	0	0	1	0

New York City

	2019	2020	2021	2022	2023
Fires	30	44	104	220	97
Injuries	13	23	79	147	64
Deaths	0	0	4	6	9

Chart: Dilcia Mercedes, CBS News • Source: New York City and San Francisco Fire Departments

Scooters, Hoverboards, Flashlights, & Other

Injuries:

- **Electric scooter** battery explosion – combination of partial and full thickness burns affecting upper and lower limbs
- Spontaneous combustions from **flashlight** – injuries to the back of your mouth and throat especially the soft and hard tissues

(Segalovich et al., 2022, Morse et al., 2019)

Source: (Segalovich et al., 2022)

Source: (Morse et al., 2019)

Source: (Morse et al., 2019)

LOCAL NEWS

Exploding vapes and e-cigarettes causing burn injuries

https://www.localsyr.com/news/local-news/exploding-vapes-and-e-cigarette

ies/

What's Causing Some E-Cigarette Batteries to Explode?

Electronic cigarettes are supposed to be the safer way to get your nicotine fix. But old fashioned cigarettes don't explode in your pocket.

-s-causing-some-e-cigarette-batteries-explode-n533516

Fort Worth man suffers 3rd degree burns after e-cigarette explodes in his pocket

https://abc13.com/ecigarette-explosion-ecig-fort-worth-explodes-in-mans-pocket/4284661/

News > World > Americas

US teenager left with third-degree burns after e-cigarette battery explodes in his pocket

Marcus Forzani says it looked like 'someone was welding in my pocket' when the device went off

https://www.independent.co.uk/news/world/americas/us-teenager-left-with-thirddegree-burns-after-ecigarette-battery-explodes-in-his-pocket-a6906011.html

E-cigs are exploding in vapers' mouths, leavin gruesome injuries

https://www.seattletimes.com/seattle-news/health/exploding-e-cigarettes-send-vapers-to-harborview-with-gruesome-injuries/

HEALTH & WELLNESS

Vape pen explodes on 17-year-old, shattering his jaw and knocking out teeth

's not alone: There were 2,035 visits to U.S. emergency rooms from 2015 to 7 for e-cigarette burns and explosion-related injuries.

This Teen Hopes Photos Of His Severely Burned Leg Will Show Why Vape Pens Can Be Dangerous

Marcus Forzani will require multiple surgeries after suffering second- and third-degree burns on most of his left leg. WARNING: Some images may be ing to readers.

https://www.buzzfeednews.com/article/stephaniemcneal/vape-pen-horror

HEALTH

New York teen badly injured by exploding e-cigarette

https://www.cbsnews.com/news/new-york-teen-badly-injured-by-exploding-e-cigarette/

CALIFORNIA CUPA FORUM

Burns from Vaping Injuries

Injuries:

- E-cigarette facial burns and damage
- Mouth, jaw, and face fractures
- Blurred vision
- Decreased hearing
- Second- and third-degree burns
- Projectile wound to the head
- Injuries to the hands, waist/genetalia
- Combustion injury to the maxilla
- Injuries to left and right lower extremities – thigh and groin areas most common
- Right chest injury with blisters

(Aranaout et al., 2017, Archambeau et al., 2016, Bauman et al., 2017, Bohr et al., 2016, Boissiere et al., 2020, Jiwani et al., 2017, Journal of Forensic Science, Kaltenborn et al., 2023, Kite et al., 2016, Maraqa et al., 2017, Nicoll et al., 2016, Treitl et al., 2017, Vyncke et al., 2020, Walsh et al., 2016)

Source: (Aranaout et al., 2017)

Source: (Archambeau et al., 2016)

Source: (Kaltenborn et al., 2023)

Figure 5 Burning of the flank by the explosion of an electronic cigarette battery inside the pocket of a jacket.

Source: (Boissiere et al., 2020)

Bike rider dies near Paramakudi after his mobile phone explodes

https://www.thehindu.com/news/cities/Madurai/bike-rider-dies-after-his-mobile-phone-exploded-near-paramakudi/article68429840.ece

Person injured after cellphone explodes at DC high school

Fire officials said the phone exploded due to a lithium-ion battery failure

https://www.foxbusiness.com/technology/person-injured-cellphone-explodes-dc-high-school

A 13-Year-Old Girl Allegedly Suffered Second-Degree Burns From Her Cell Phone

"This is an issue that parents s

://www.buzzfeednews.com/article/stephaniemcnea

8-year-old child in AP sustains burn injuries after cell phone explodes in his hands

The explosion nearly severed three of his fingers too; but he is undergoing treatment in hospital and is out of danger.

https://www.thenewsminute.com/andhra-pradesh/8-year-old-child-ap-sustains-burn

e-explodes-his-

hands-85634

Passenger suffers burns after cell ph catches fire on plane

An Air Canada flight was preparing for takeoff when a cell phone cau

https://abcnews.go.com/International/passenger-suffers-burns-cell-phone-catches-fire-plane/story?id=53444916

This couple suffered severe burns because their mobile phones exploded while charging - This is what you shouldn't do

Alif Azizan - Dec 30, 2023

https://technave.com/gadget/This-couple-suffered-severe-burns-because-their-mobile-phones-exploded-while-charging-This-is-what-you-shouldn-t-do-37056.html

4 kids burnt to death due to fire caused by mobile phone charger: Here's how parents can prevent such accidents at home

https://timesofindia.indiatimes.com/life-style/parenting/moments/4-kids-burnt-to-death-due-to-fire-caused-by-mobile-phone-charger-heres-how-parents-can-prevent-such-accidents-at-home/articleshow/1088

EXCLUSIVE: Long Island man burned on leg by iPhone when it exploded

https://abc7ny.com/long-island-iphone-explodes-burn-man-burned-by/536552/

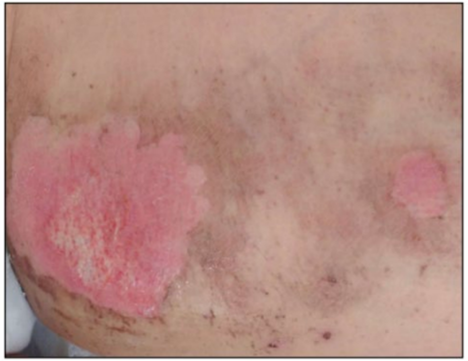
CALIFORNIA CUPA FORUM

Burn Injuries from Cellphones

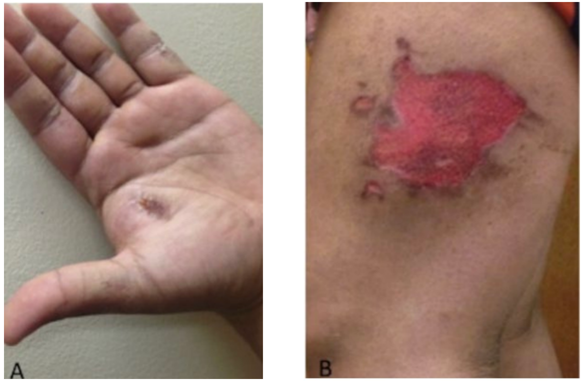
Injuries:

- Thermal burns
- Second- and third-degree burns
- Burns to the fingers and lower extremities
  - Left lateral thigh
- Partial thickness burns

(Corazza et al., 2018, Cherubino et al., 2016, Atreya et al., 2016, Des Robert et al., 2023, Hagiwara et al., 2021, Mankowski et al., 2016)



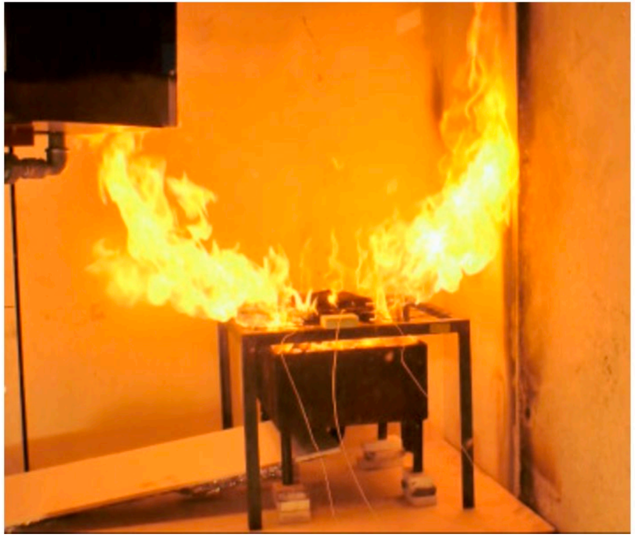
Source: (Corazzaa et al., 2017)



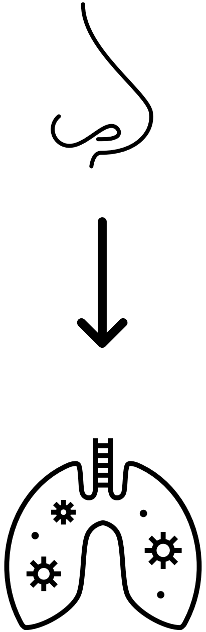
Source: (Mankowski et al., 2016)

Source: (Hagiwara et al., 2021)

Chamber Studies on Emissions from LIBs



What chemicals are emitted from LIBs?



VOCs

PF_3

HCl

NOx

H_2

Metals

HCN

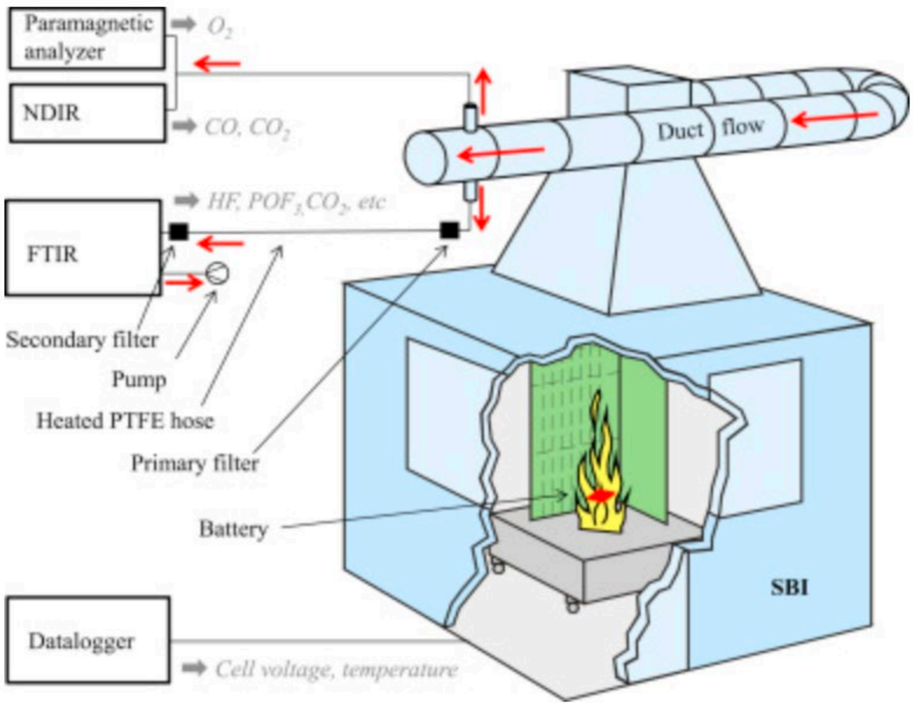
PF_5

$LiPF_6$

27th California Unified Program
Annual Training Conference
March 24-27, 2025

Chamber Studies on Emissions from Lithium-Ion Batteries

- LIB batteries placed into a chamber
- Emissions from batteries measured



"Characteristics of lithium-ion batteries during fire tests" (Larsson et al., 2014)

https://www.sciencedirect.com/science/article/abs/pii/S0378775314012828

- **Purpose**:
  - Conducted six abuse tests on cells having LFP cathodes
  - Compared to laptop battery packs with cobalt cathodes
  - Determined gas emissions and voltage variations under fire conditions
- **Methods used**:
  - Performed fire tests, measured heat release rate (HRR), gas emissions, cell temperature & voltage
- **Equipment**:
  - Single Burning Item (SBI) apparatus for fire testing, Fourier Transform Infrared Spectroscopy (FTIR)
- **Results**:
  - Hydrogen Fluoride (HF) detected in all tests
  - Phosphoryl fluoride (POF_3) not found in significant amounts
  - Higher HF emissions at lower states of charge (SOC)

"Characteristics of lithium-ion batteries during fire tests" Larsson et al., 2014

https://www.sciencedirect.com/science/article/abs/pii/S0378775314012828

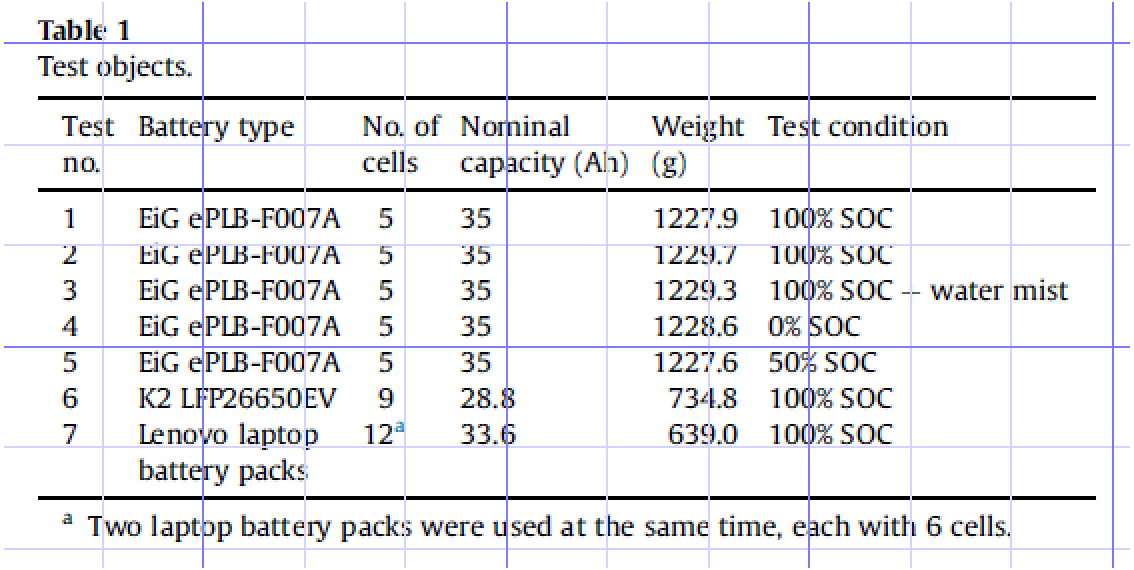


Table 1

Test objects.

Test no.	Battery type	No. of cells	Nominal capacity (Ah)	Weight (g)	Test condition
1	EiG ePLB-F007A	5	35	1227.9	100% SOC
2	EiG ePLB-F007A	5	35	1229.7	100% SOC
3	EiG ePLB-F007A	5	35	1229.3	100% SOC – water mist
4	EiG ePLB-F007A	5	35	1228.6	0% SOC
5	EiG ePLB-F007A	5	35	1227.6	50% SOC
6	K2 LFP26650EV	9	28.8	734.8	100% SOC
7	Lenovo laptop battery packs	12[a]	33.6	639.0	100% SOC

[a] Two laptop battery packs were used at the same time, each with 6 cells.

"Characteristics of lithium-ion batteries during fire tests" Larsson et al., 2014

https://www.sciencedirect.com/science/article/abs/pii/S0378775314012828

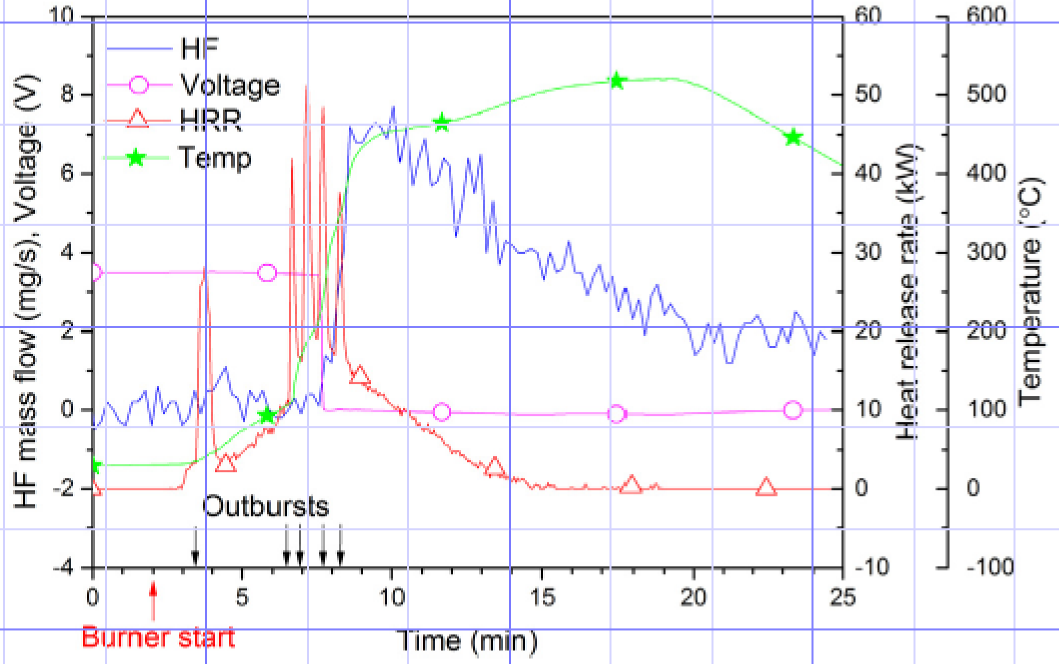
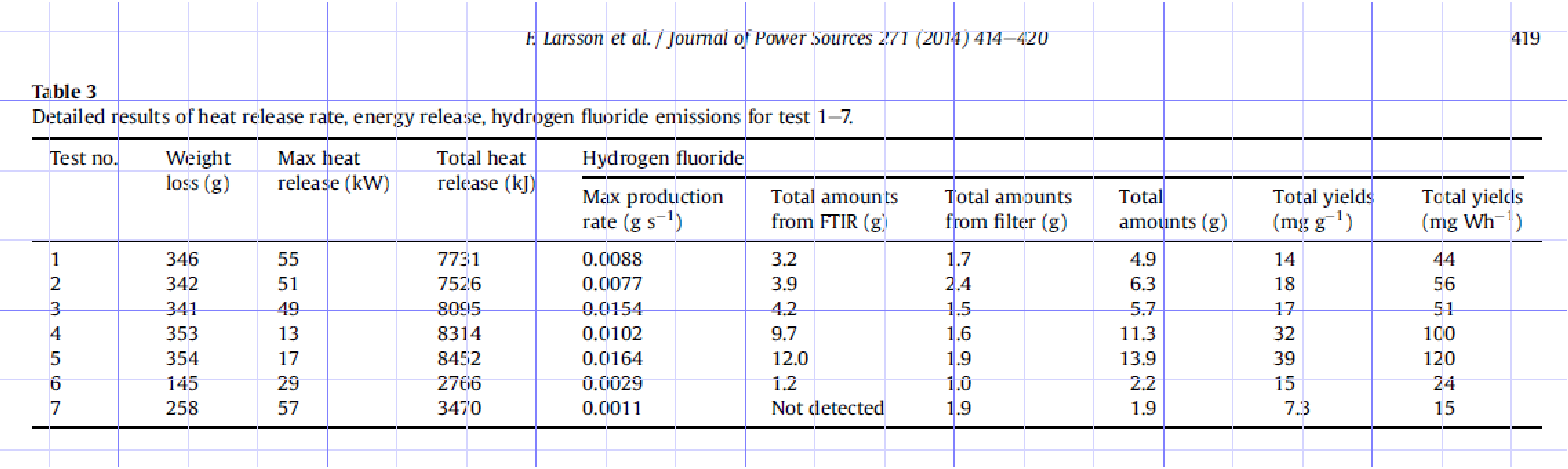


Fig. 7. Resultsf EiG 100% SOC (test 2).

"Characteristics of lithium-ion batteries during fire tests" Larsson et al., 2014

https://www.sciencedirect.com/science/article/abs/pii/S0378775314012828



F. Larsson et al. / Journal of Power Sources 271 (2014) 414–420 419

Table 3

Detailed results of heat release rate, energy release, hydrogen fluoride emissions for test 1–7.

Test no.	Weight loss (g)	Max heat release (kW)	Total heat release (kJ)	Hydrogen fluoride					
				Max production rate (g s^{-1})	Total amounts from FTIR (g)	Total amounts from filter (g)	Total amounts (g)	Total yields (mg g^{-1})	Total yields (mg Wh^{-1})
1	346	55	7731	0.0088	3.2	1.7	4.9	14	44
2	342	51	7526	0.0077	3.9	2.4	6.3	18	56
3	341	49	8095	0.0154	4.2	1.5	5.7	17	51
4	353	13	8314	0.0102	9.7	1.6	11.3	32	100
5	354	17	8452	0.0164	12.0	1.9	13.9	39	120
6	145	29	2766	0.0029	1.2	1.0	2.2	15	24
7	258	57	3470	0.0011	Not detected	1.9	1.9	7.3	15

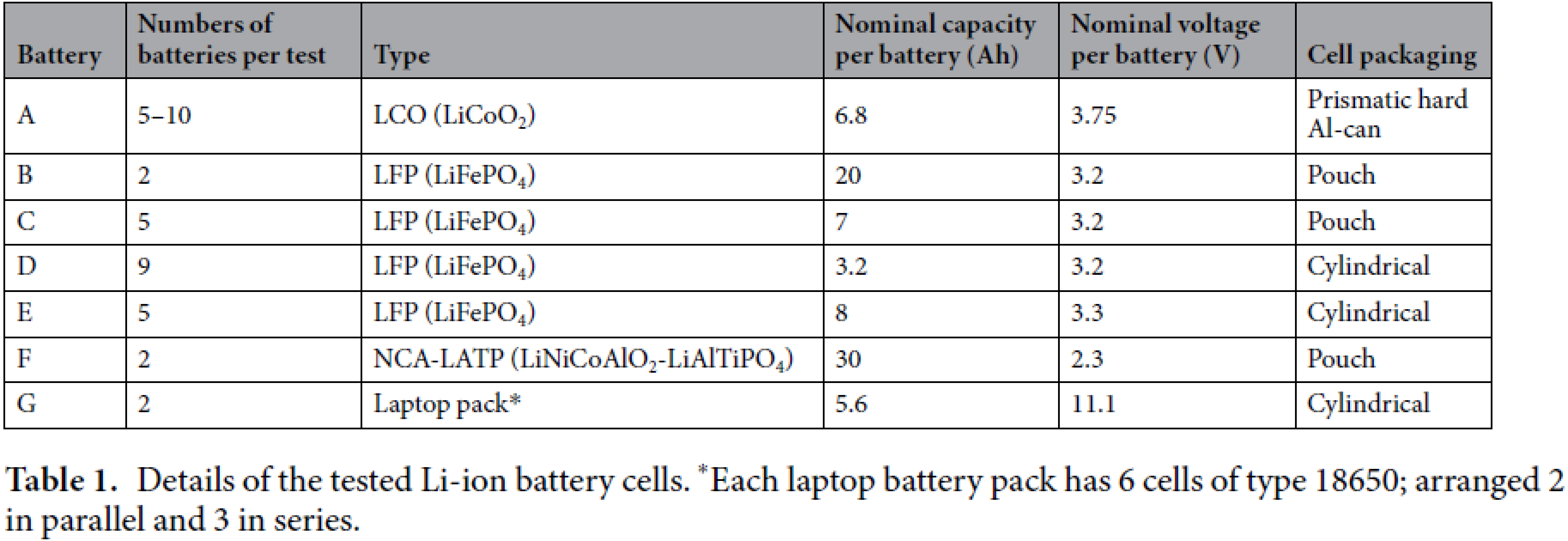
"Toxic fluoride gas emissions from lithium-ion battery fires" (Larsson et al., 2017)

- **Purpose**:
  - Quantitative measurements of heat release and fluoride gas emissions
  - Battery fires for seven different types of commercial lithium-ion batteries
- **Methods used**:
  - External propane fire
  - Measured fire characteristics, gas emissions, battery temperatures and cell voltages
- **Equipment**:
  - FTIR

"Toxic fluoride gas emissions from lithium-ion battery fires" (Larsson et al., 2017)

- **Results**:
  - Generated large amounts of hydrogen fluoride (HF) ranging between 20 and 200 mg/Wh of nominal battery energy capacity
  - Measured phosphoryl fluoride 15–22 mg/Wh in some of the fire tests (only in one of the cell types and only at 0% SOC)
  - Varied with different types of batteries and states of charge (SOC) levels

"Toxic fluoride gas emissions from lithium-ion battery fires" (Larsson et al., 2017)



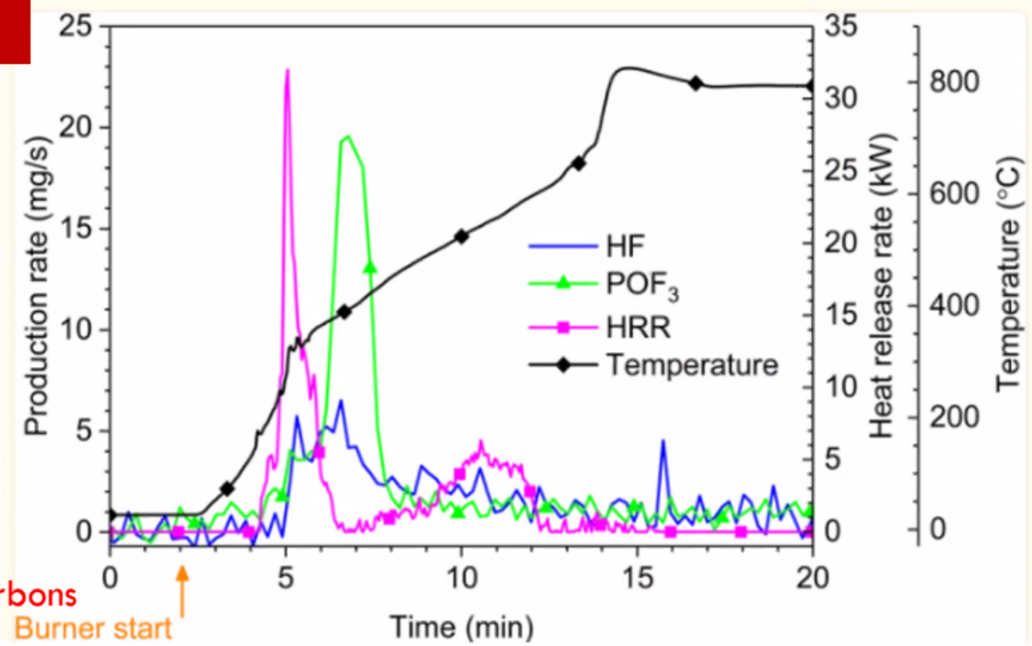
Battery	Numbers of batteries per test	Type	Nominal capacity per battery (Ah)	Nominal voltage per battery (V)	Cell packaging
A	5–10	LCO ($LiCoO_2$)	6.8	3.75	Prismatic hard Al-can
B	2	LFP ($LiFePO_4$)	20	3.2	Pouch
C	5	LFP ($LiFePO_4$)	7	3.2	Pouch
D	9	LFP ($LiFePO_4$)	3.2	3.2	Cylindrical
E	5	LFP ($LiFePO_4$)	8	3.3	Cylindrical
F	2	NCA-LATP ($LiNiCoAlO_2$-$LiAlTiPO_4$)	30	2.3	Pouch
G	2	Laptop pack*	5.6	11.1	Cylindrical

Table 1. Details of the tested Li-ion battery cells. *Each laptop battery pack has 6 cells of type 18650; arranged 2 in parallel and 3 in series.

Li-Ion Battery Toxic/Flammable Vapors

Toxic/Flam Vapors

- Hydrogen (30%-50%)
- Carbon Monoxide
- Hydrogen Fluoride
- Hydrogen Chloride
- Hydrogen Cyanide
- Phosphoryl Fluoride
- Organic Solvent Droplets
- Ethane, methane, and other hydrocarbons



Source: Toxic fluoride gas emissions from lithium-ion battery fires. Larsson F, Andersson P, Blomqvist P, Mellander BE. Sci Rep. 2017 Aug 30;7(1):10018. doi: 10.1038/s41598-017-09784-z. Erratum in: Sci Rep.

"Lithium-ion battery explosion aerosols: Morphology and elemental composition" (Barone et al., 2021)

https://pmc.ncbi.nlm.nih.gov/articles/PMC9345575/

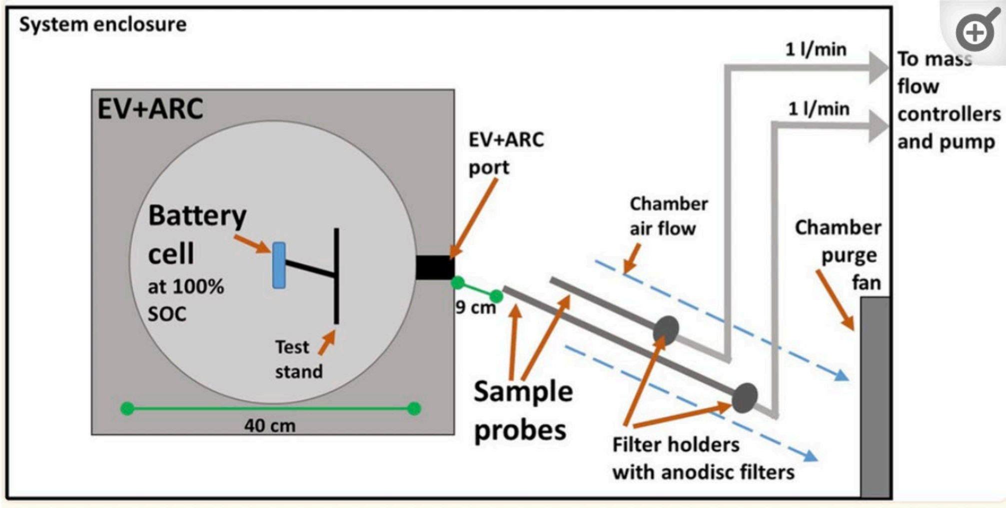
- **Purpose**: Aimed to characterize aerosols from thermal runaway events in three different battery types: Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Iron Phosphate (LFP), & Lithium Titanate Oxide (LTO)
- **Methods used**: Battery cells were fully charged and heated in an accelerating rate calorimeter (ARC), aerosols were collected on anodisc filters
- **Equipment**: Scanning electron microscopy (SEM) to study aerosol morphology, Energy-Dispersive X-ray Spectroscopy (EDS)
- **Results**: **NMC battery**: Exploded with intense heat and ejected embers, **LFP battery**: Emitted sustained smoke but remained intact, **LTO battery**: Similar to LFP but with partial ejection of cell contents.

NMC cell exploded more intensely over a shorter period of time – anode and cathode fragments

LFP and LTO cells remained in sample holder emitting smoke

Analysis – shows composition of explosion aerosols

"Lithium-ion battery explosion aerosols: Morphology and elemental composition" (Barone et al., 2021)
https://pmc.ncbi.nlm.nih.gov/articles/PMC9345575/



https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9345575/

"Toxicity Identification and Evolution Mechanism of Thermolysis-Driven Gas Emissions from Cathodes of Spent Lithium-ion Batteries" (Chen et al., 2019)

https://pubs.acs.org/doi/epdf/10.1021/acssuschemeng.9b03739?ref=article_openPDF

- **Purpose**: To understand the characteristics of the off-gases generated from spent LIBs cathodes during the thermolysis process
- **Methods used**: Thermogravimetric/ differential scanning calorimetry (TG-DSC), MS signals from gas emissions recorded in real-time
- **Equipment**: Mass spectrometry equipped with skimmer-type interface and electron ionization (TG-DSC-EI-MS), chemical analysis, X-ray diffraction (XRD), and scanning electron microscopy (SEM)
- **Results**: Gases of H_2, CO_2, gaseous hydrocarbons, and fluoride-containing gases were generated

"Toxicity, Emissions and Structural Damage from Lithium-ion Battery Thermal Runaway" (Zhou et al., 2019)

https://pubs.acs.org/doi/epdf/10.1021/acssuschemeng.9b03739?ref=article_openPDF

- **Purpose**: Utilized the electrothermal triggering method to study thermal runaway behaviors of 3 commercial batteries (NMC, LCO, & LFP)
- **Methods**: Used an explosion-proof box as experimental platform, LIBs were heated on a heating plate filmed by a camera
  - Collected gas samples after explosion with an air sampler and analyzed by Hapsite Smart
- **Equipment**: SEM, TEM, and x-ray diffraction (XRD) used to observe structural damage of the cathode material, qualitative analysis from LIBs used GC-MS
- **Results**: Toxic substances found were 2-propenal, methyl vinyl ketone, propanedinitrile, 1,2-dimethyl-hydrazine, and thiocyanic acid ethyl ester

Zhou et al., 2023

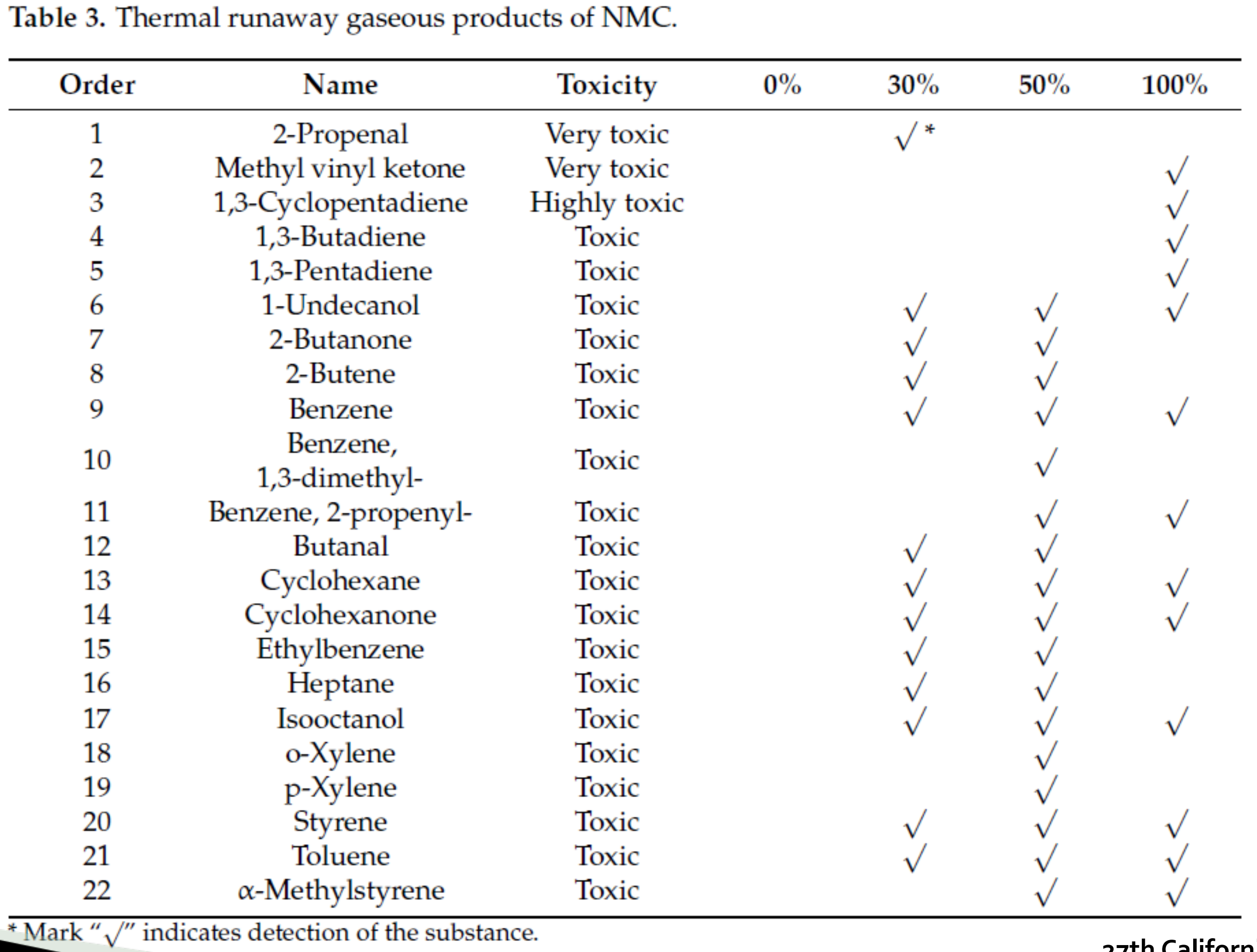


Table 3. Thermal runaway gaseous products of NMC.

Order	Name	Toxicity	0%	30%	50%	100%
1	2-Propenal	Very toxic		√ *		
2	Methyl vinyl ketone	Very toxic				√
3	1,3-Cyclopentadiene	Highly toxic				√
4	1,3-Butadiene	Toxic				√
5	1,3-Pentadiene	Toxic				√
6	1-Undecanol	Toxic		√	√	√
7	2-Butanone	Toxic		√	√	
8	2-Butene	Toxic		√	√	
9	Benzene	Toxic		√	√	√
10	Benzene, 1,3-dimethyl-	Toxic			√	
11	Benzene, 2-propenyl-	Toxic			√	√
12	Butanal	Toxic		√	√	
13	Cyclohexane	Toxic		√	√	√
14	Cyclohexanone	Toxic		√	√	√
15	Ethylbenzene	Toxic		√	√	
16	Heptane	Toxic		√	√	
17	Isooctanol	Toxic		√	√	√
18	o-Xylene	Toxic			√	
19	p-Xylene	Toxic			√	
20	Styrene	Toxic		√	√	√
21	Toluene	Toxic		√	√	√
22	α-Methylstyrene	Toxic			√	√

* Mark "√" indicates detection of the substance.

"Analysis of Li-Ion Battery Gases Vented in an Inert Atmosphere Thermal Test Chamber“ (Sturk et al., 2019)

https://www.mdpi.com/2313-0105/5/3/61

- **Purpose**: Measure gas emissions in the absence of flames since gassing can occur without a subsequent fire
- **Methods**: Utilized test vessel with insulated walls and plate heater on the bottom (power was 1500W), two sampling lines connected to heating duct
- **Equipment**: FTIR used to detect amounts of HF, FTIR spectra from LFP (lighter weight) and NMC cell types are from carbonates
- **Results**: Total HF amounts released from LFP and NMC/LMO are comparable; however, HF gases released from LFP cells are more than an order of magnitude higher than NMC/LMO

"Analysis of Li-Ion Battery Gases Vented in an Inert Atmosphere Thermal Test Chamber“ (Sturk et al., 2019)

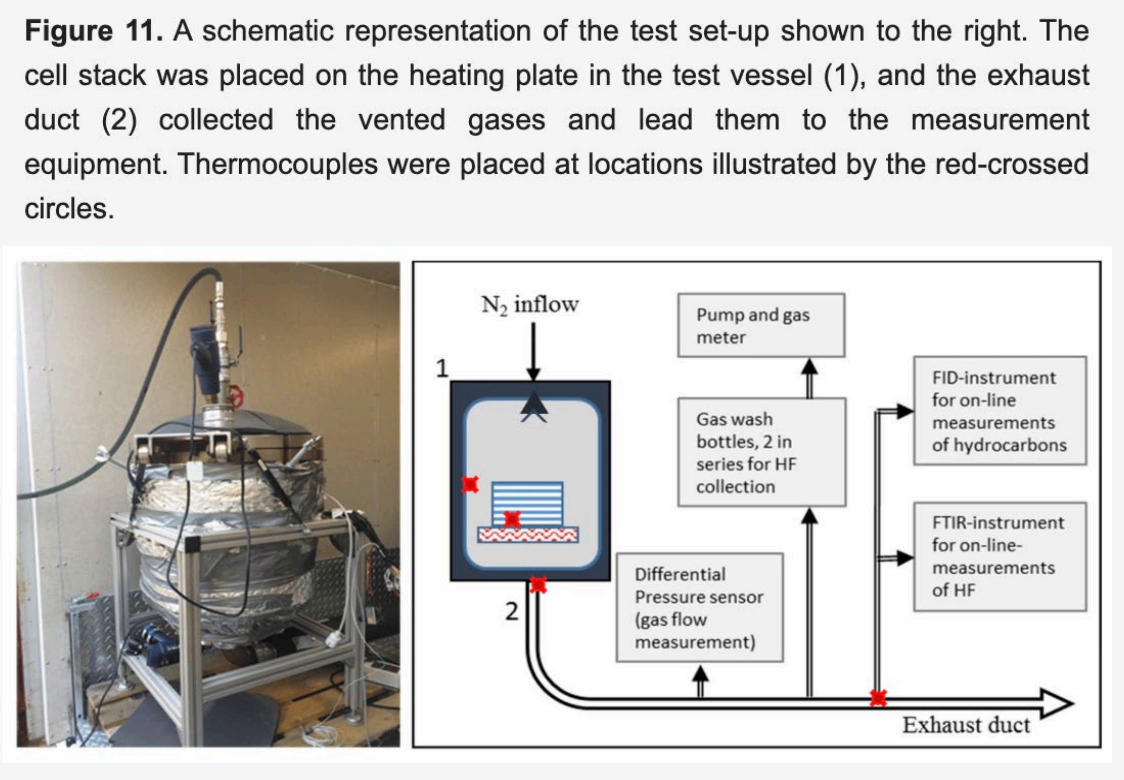


Figure 11. A schematic representation of the test set-up shown to the right. The cell stack was placed on the heating plate in the test vessel (1), and the exhaust duct (2) collected the vented gases and lead them to the measurement equipment. Thermocouples were placed at locations illustrated by the red-crossed circles.

"Composition and Explosibility of Gas Emissions from Lithium-Ion Batteries Undergoing Thermal Runaway " (Amano et al., 2023)

https://www.mdpi.com/2313-0105/9/6/300

- **Purpose**: Assess explosivity of gaseous emissions from LIBs of an **NMC** battery runaway
- **Methods**: Pouch lithium-based battery cells were exposed to abuse conditions when placed in a closed vessel
- **Equipment**: FTIR analyzed composition of gases by state of charge levels

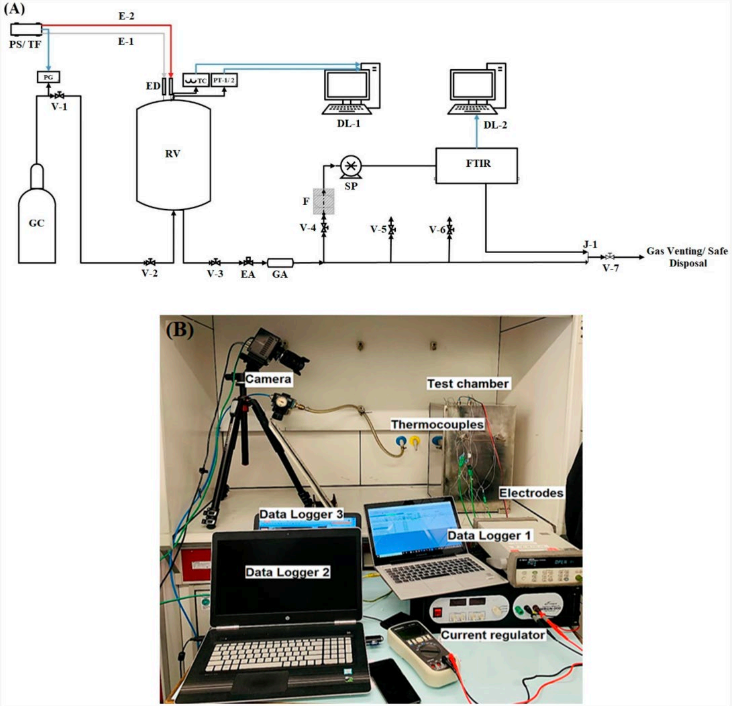


Figure 2. (**A**) Schematic representation of the experimental setup used for the thermal runaway in test series 1 and 2; (**B**) test series 3.

"Composition and Explosibility of Gas Emissions from Lithium-Ion Batteries Undergoing Thermal Runaway " (Amano et al., 2023)

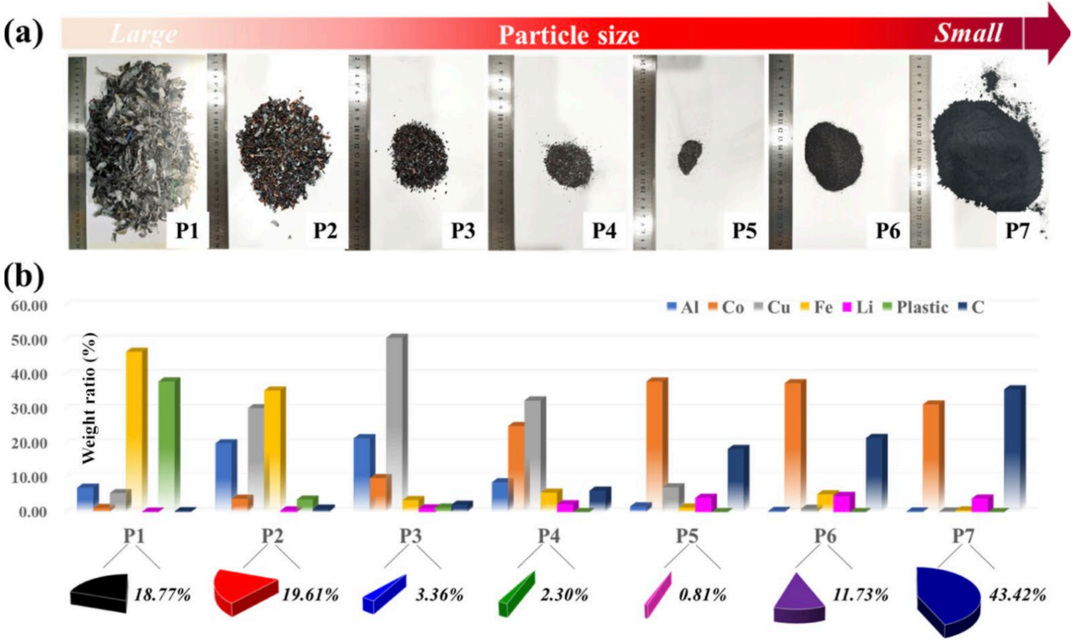
- **Results**:
  - Found carbon monoxide (CO), methane (CH_4), ethylene (C_2H_4), ethane (C_2H_6), and hydrogen cyanide (HCN)
  - The tests performed in enclosed vessels showed hot gas ejected and secondary explosion
  - Released gases was up to 102 ± 4 L, with a clear dependence on the battery capacity
  - Emissions increased with higher cell capacity
  - Maximum concentrations of flammable gases within explosive range
    - carbon monoxide (16.85 vol%), methane (7.6 vol%), and ethylene (7.86 vol%)

"Migration and Transformation Mechanism of Toxic Electrolytes During Mechanical Treatment of Spent Lithium-Ion Batteries " (Xiao et al., 2023) https://pubs.acs.org/doi/10.1021/acssuschemeng.2c07116

- **Purpose**: Determine the migration and transformation of toxic electrolytes during mechanical treatment of spent LIBs
- **Methods**: Spent LIBs manually dismantled from lap-top and then discharged in 1.5 mol/L $MnSO_4$ solution for 24 hours
  - Then, 20 batteries were processed by mechanical treatment – gaseous products collected through a gas collect point after crushing
- **Equipment**:
  - Inductively coupled plasma emission spectrometry (ICP-AES)
  - Elemental analyzer
  - GC-MS

"Migration and Transformation Mechanism of Toxic Electrolytes During Mechanical Treatment of Spent Lithium-Ion Batteries “ (Xiao et al., 2023)

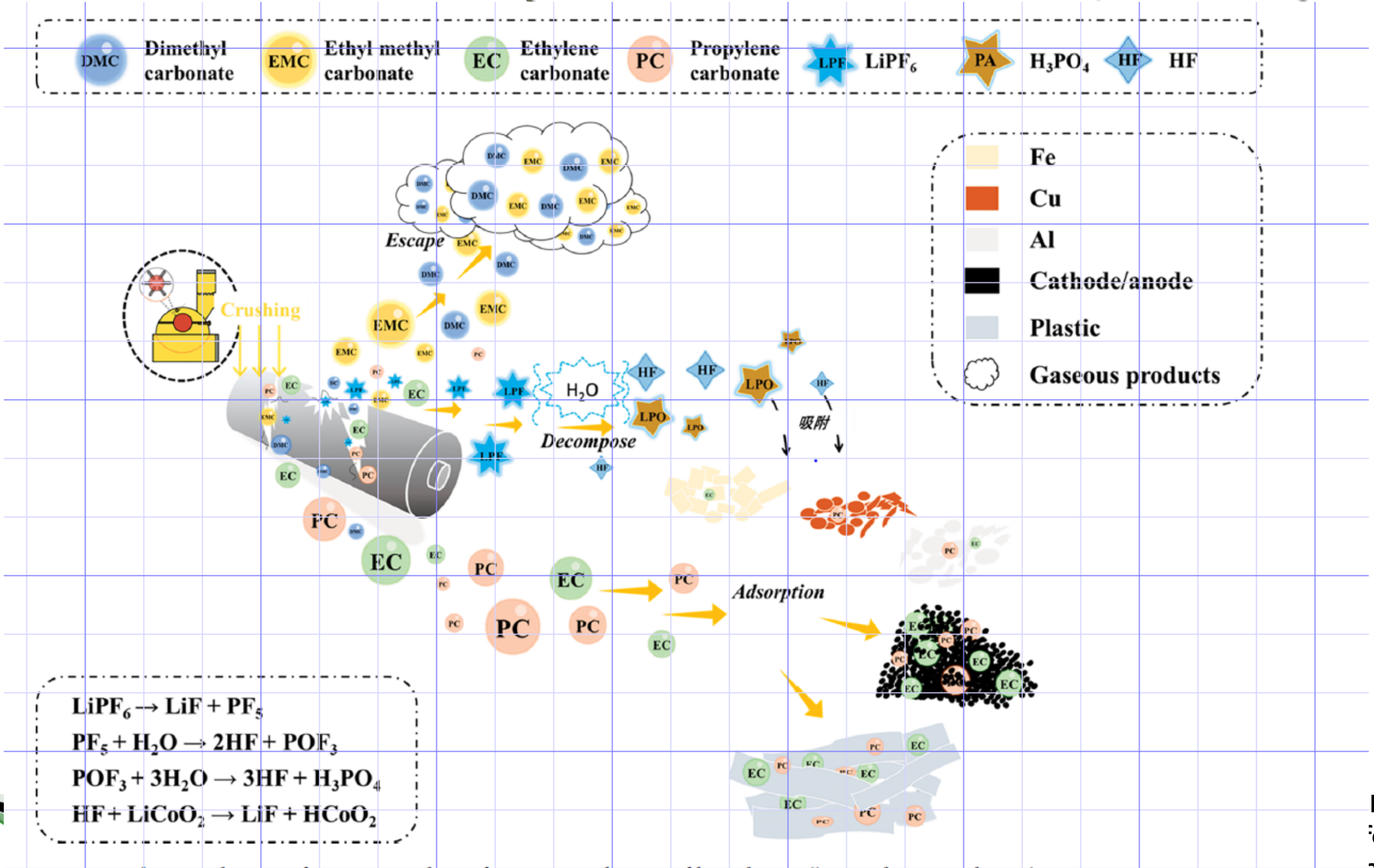
Figure 3. (a) Images of different PSPs (**P1–P7**) after mechanical treatments; (b) mass distribution and chemical compositions of different PSPs (**P1–P7**) (crushing conditions: 2000 rpm, 1 min).



"Migration and Transformation Mechanism of Toxic Electrolytes During Mechanical Treatment of Spent Lithium-Ion Batteries " (Xiao et al., 2023)

- **Results**:
  - Strip-shaped components (shell, Cu/Al foil, and separator) were converted into large/middle particle size products (PSPs),
  - Powdery components (cathode, binder, and anode) were converted into small particles by mechanical force
  - Liquid electrolytes released irritant gases: dimethyl carbonate (DMC), ethyl methyl carbonate (EMC), ethylene carbonate (EC), propylene carbonate (PC), and lithium hexafluorophosphate (LiPF6)
  - No fluoride-containing products detected by GC-MS

"Migration and Transformation Mechanism of Toxic Electrolytes During Mechanical Treatment of Spent Lithium-Ion Batteries " (Xiao et al., 2023)



$$LiPF_6 \rightarrow LiF + PF_5$$

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

$$POF_3 + 3H_2O \rightarrow 3HF + H_3PO_4$$

$$HF + LiCoO_2 \rightarrow LiF + HCoO_2$$

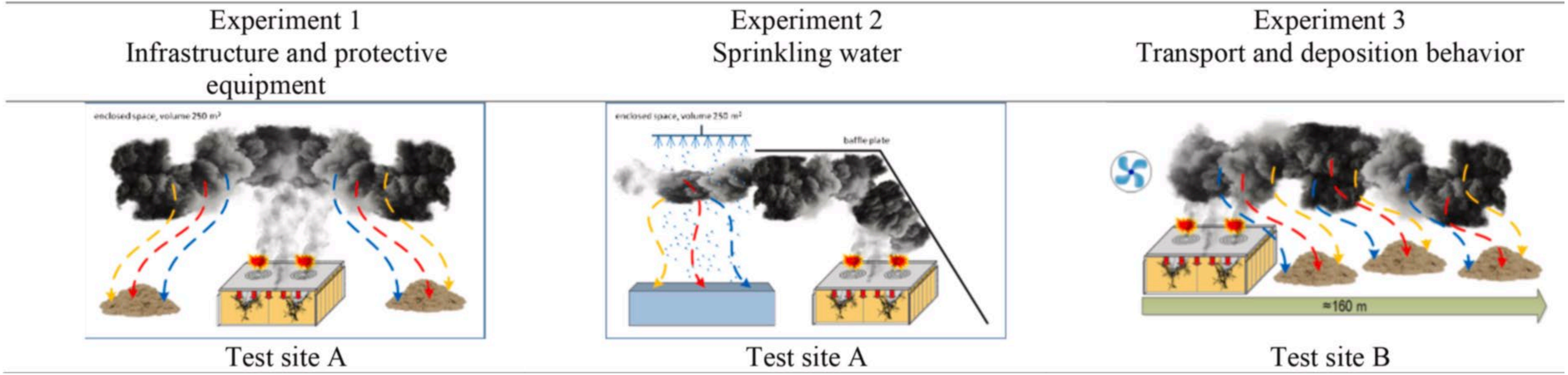
Figure 9. Schematic diagram of migration and transformation mechanism of hazardous pollutants during mechanical treatment.

"Thermal runaway and fire of electric vehicle lithium-ion battery and contamination of infrastructure facility " (Held et al., 2022)

https://www.sciencedirect.com/science/article/pii/S1364032122003793

- **Purpose**: Performed thermal runaway experiments on EV LIB to determine contamination
- **Methods**: Three different test scenarios:
  1) infrastructure and protective equipment,
  2) sprinkling and storage water,
  3) transport and deposition behavior
  - Focused on 'cold fire site' analyzing residues instead of gas analyses
- **Equipment**:
  - SEM-EDX analysis to determine Co, Ni, Mn (heavy metals) presence,
  - Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) analysis of nitric acid extract of fire soot

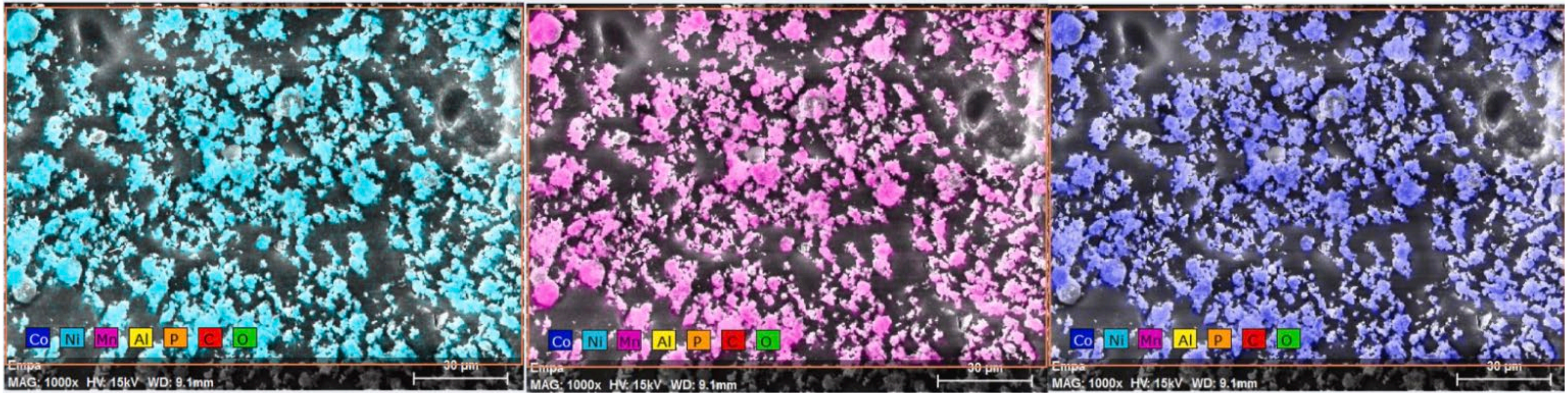
"Thermal runaway and fire of electric vehicle lithium-ion battery and contamination of infrastructure facility " (Held et al., 2022)



Experiment 1 Infrastructure and protective equipment	Experiment 2 Sprinkling water	Experiment 3 Transport and deposition behavior
Test site A	Test site A	Test site B

"Thermal runaway and fire of electric vehicle lithium-ion battery and contamination of infrastructure facility " (Held et al., 2022)

Fig. 12. Close-up of soot on printed circuit boards in PC.



"Thermal runaway and fire of electric vehicle lithium-ion battery and contamination of infrastructure facility " (Held et al., 2022)

- **Results**: Fire soot quantified on collector plates in the test tunnels, consisting mainly of heavy metal oxides

SEM-EDX

- Co, Ni, Mn made up 25% by mass, O was detected with a concentration of 15-20%
- Al, C, F, and P made up 1-5% by mass

ICP-OES

- Co, Ni, and Mn made up 17-18% by mass, and Li was detected at a 3% concentration by mass
- Organic pollutants such as polycyclic aromatic hydrocarbons (PAHs) were detected at levels exceeding background contamination levels by a factor of up to 50

Chamber Laboratory Studies by Battery Type

NMC Battery:

(Amano et al., 2023; Essl et al., 2020, Barone et al., 2021, Nedjalkov et al., 2016, Premnath et al., 2022, Qiu et al., 2023, Quant et al., 2023, Long Jr. Et al., 2011, Stephens et al., 2017, Sturk et al., 2019, Sun et al., 2016, McKinnon et al., 2020, Wang et al., 2023, Zackrisson et al., 2020, Zhou et al., 2023)

LFP Battery:

(Peng et al., 2020, Anderson et al., 2013, Barone et al., 2021, Fernandes et al., 2018, Larsson et al., 2014, Larsson et al., 2017, Lecoq et al., 2016, Mellander and Larsson, 2020, Premnath et al., 2022, Qiu et al., 2023, Stephens et al., 2017, Sturk et al., 2019, Sun et al., 2016, Wang et al., 2023, Zackrission et al., 2020, Zhou et al ., 2023)

LTO Battery:

(Barone et al., 2021, Stephens et al., 2017)

Field Studies in San Diego (US EPA 2024)

Chemical Name	CAS #
Hydrogen Fluoride (HF)	7664-39-3
Lithium Hydroxide (LiOH)	1310-65-2
Hydrogen Cyanide (HCN)	74-90-8
Lithium Hexafluorophosphate	21324-40-3
Phosphoric trifluoride	7783-55-3
Phosphorous Pentafluoride	10026-13-8
Hydrogen Chloride	7647-01-0
Hydrogen Gas	1333-74-0

Chemical Name	CAS #
Cobalt (Co)	7440-48-4
Copper (Cu)	7440-50-8
Nickel (Ni)	7440-02-0
Antimony (Sb)	7440-36-0
Lead (Pb)	7439-92-1
Zinc (Zn)	7440-66-6
Aluminum (Al)	7429-90-5
Silver (Ag)	7440-22-4
Tin (Sn)	7440-31-5
Volatile Organic Compounds (VOCs)	Chemical Class

Summary of Chemicals Emitted from LIBs

Metals

- Aluminum (Al)
- Antimony (Sb)
- Arsenic (As)
- Cobalt (Co)
- Copper (Cu)
- Lead (Pb)
- Nickel (Ni)
- Manganese (Mn)
- Molybdenum (Mo)
- Silver (Ag)
- Tin (Sn)
- Titanium (Ti)
- Zinc (Zn)

Gases

- Carbon Monoxide (CO)
- Ethane (C_2H_6)
- Formaldehyde (CH_2O)
- Hydrogen (H_2)
- Hydrogen Chloride (HCl)
- Hydrogen Cyanide (HCN)
- Hydrogen Fluoride (HF)
- Methane (CH_4)
- Nitrogen dioxide (NO_2)
- Sulfur dioxide (SO_2)

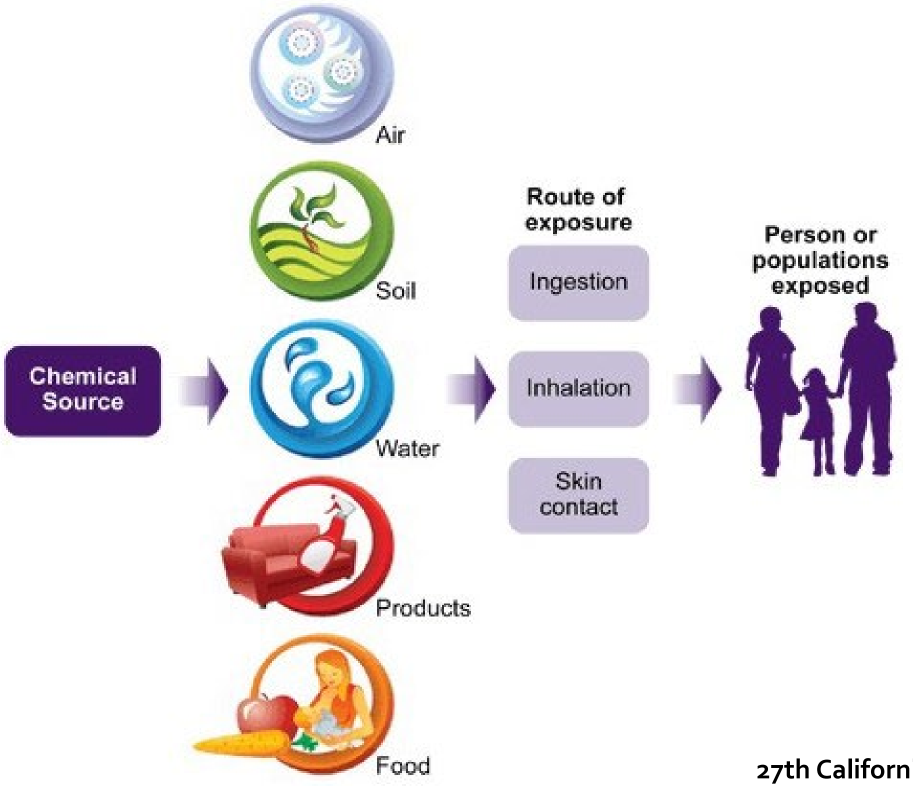
Battery-Specific

- Lithium hexafluorophosphate ($LiPF_6$)
- Lithium hydroxide (LiOH)
- Phosphorous Pentafluoride (PF_5)
- Phosphorous trifluoride (POF_3)
- Per- and poly-fluoroalkyl substances (PFAS)

Chemical Categories of Interest

Acid Gases (HF, HCL, HCN, H)
Carbon monoxide
Metals
PAHs
Particulate Matter (PM2.5 and PM10)
Volatile Organic Compounds (VOCs)
Hydrocarbons
Battery-Specific chemicals (fluorides and Lithium oxide/salts

Exposure Assessment of LIBs



Chemical Source

Air

Soil

Water

Products

Food

Route of exposure

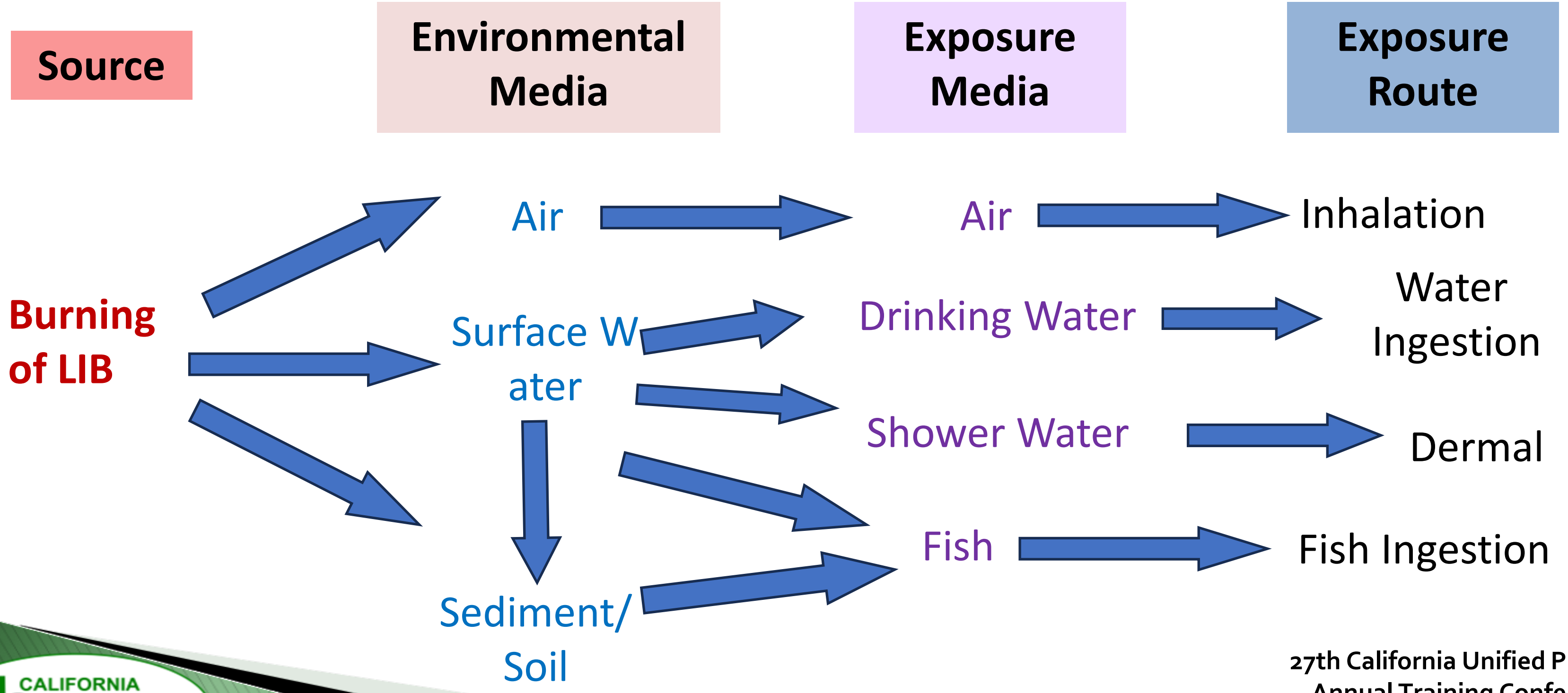
Ingestion

Inhalation

Skin contact

Person or populations exposed

Potential Exposure Pathway from LIB fires



Source

Environmental Media

Exposure Media

Exposure Route

Burning of LIB

Air

Surface Water

Sediment/ Soil

Air

Drinking Water

Shower Water

Fish

Inhalation

Water Ingestion

Dermal

Fish Ingestion

Taylor & Francis Group

Journal of Toxicology and Environmental Health, Part B
Critical Reviews

ISSN: 1093-7404 (Print) 1521-6950 (Online) Journal homepage: https://www.tandfonline.com/loi/uteb20

Risk assessment of lithium-ion battery explosion: chemical leakages

Yoo Jung Park, Min Kook Kim, Hyung Sik Kim & Byung Mu Lee

To cite this article: Yoo Jung Park, Min Kook Kim, Hyung Sik Kim & 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

To link to this article: https://doi.org/10.1080/10937404.2019.1601815

Exposure Considerations

- Wildfires: During and after the fire
- Large structural fires
- Highway fires
- Risk and exposure from large amounts of batteries in storage or individual (cars, computers, charging stations) in many structures
- Real-time measurements during LIB fires present unique challenges
- Need to consider other disaster types: flooding, hurricanes, earthquakes

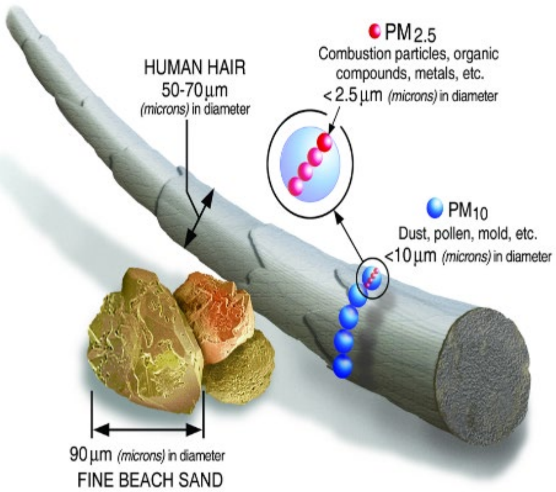
Health and Safety Information Related to Selected Chemicals of Concern

- Where do you find information on these and other chemicals?
- What information may be available?

Overview of Information for Each Chemical

1. Physical & Chemical Properties
2. Symptoms via Different Routes of Exposure
3. Acute Toxicity to Humans
4. Adverse Health Effects
5. Short-term (Acute) Health Effects
6. Regulatory health guidance values

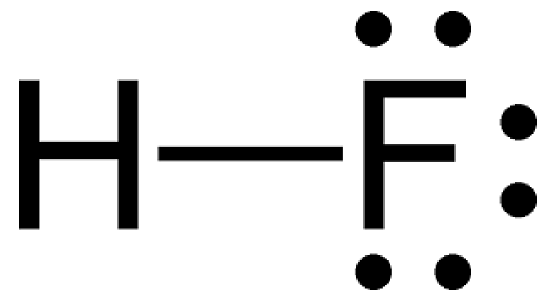
Smoke and particulate matter (PM)



- Smoke is a complex mixture that contains fine particulate matter (PM 2.5), CO, CO2, water vapor, hydrocarbons, and other organic chemicals, nitrogen oxides, and trace minerals
- Microscopic particles can penetrate deep into the lungs and cause adverse health effects
- Sensitive populations are at greater risk of experiencing health effects
- Children
- Pregnant and nursing women
- Older adults
- People with pre-existing lung and heart conditions

PM2.5 Health Effects

- PM2.5 can initiate biological pathways that can ultimately lead to health effects resulting in an emergency department visit, hospital admission, or even death.
- Documented pathways include:
  - inflammation and oxidative stress,
  - effects on the autonomic nervous system which can impact heart function, and
  - translocation of particles out of the respiratory tract into the blood where they can affect other organ systems, such as the heart.



Hydrogen Fluoride (HF)

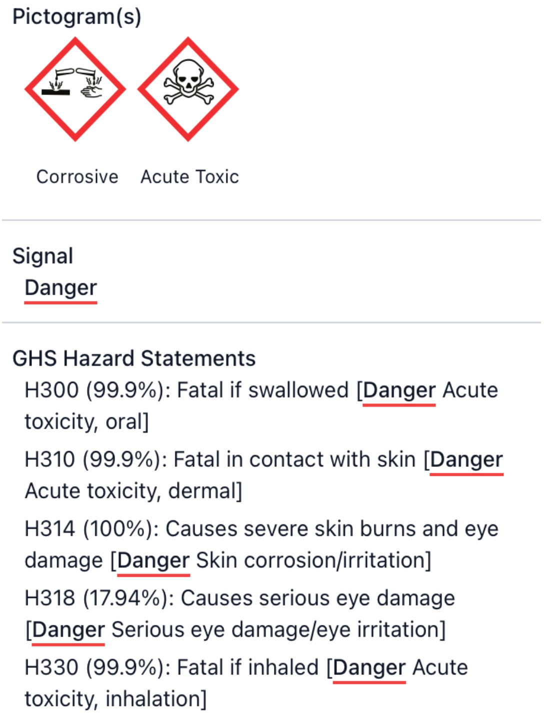
CAS #: 7664-39-3

HF: Physical and Chemical Properties

Chemical Formula	HF
Molecular Weight	20.0064 g/mol
Melting point	-83.57 °C
Boiling point	19.51°C at 400 mm Hg
Solubility	Miscible with water
Density	1.002 at 0°C
Vapor pressure	917 mm Hg at 25°C
Decomposition	When heated to decomp it emits highly corrosive fumes of hydrogen fluoride
Heat of Vaporization	7.493 kJ/mol at 101.3 kPa

Cameo Chemicals
Link for More
Information

Hydrogen Fluoride (HF)



Pictogram(s)

Signal

Danger

GHS Hazard Statements

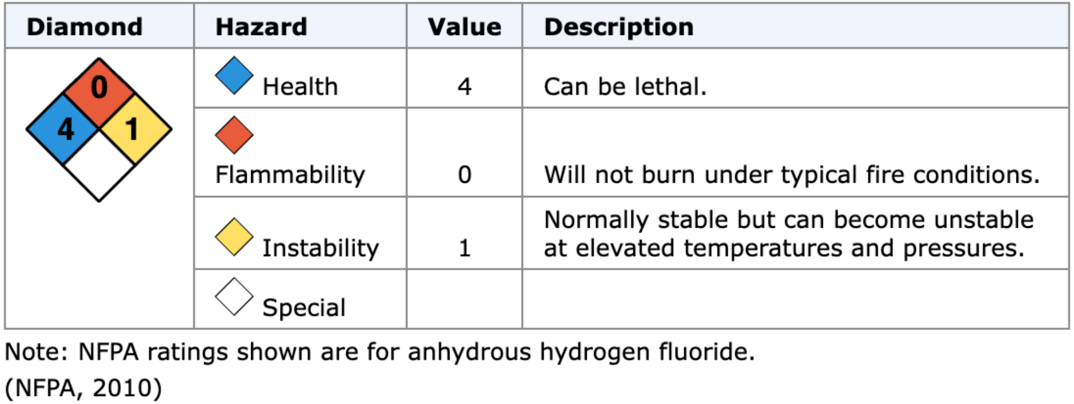
H300 (99.9%): Fatal if swallowed [Danger Acute toxicity, oral]

H310 (99.9%): Fatal in contact with skin [Danger Acute toxicity, dermal]

H314 (100%): Causes severe skin burns and eye damage [Danger Skin corrosion/irritation]

H318 (17.94%): Causes serious eye damage [Danger Serious eye damage/eye irritation]

H330 (99.9%): Fatal if inhaled [Danger Acute toxicity, inhalation]



Diamond	Hazard	Value	Description
0 4 1	Health	4	Can be lethal.
	Flammability	0	Will not burn under typical fire conditions.
	Instability	1	Normally stable but can become unstable at elevated temperatures and pressures.
	Special		

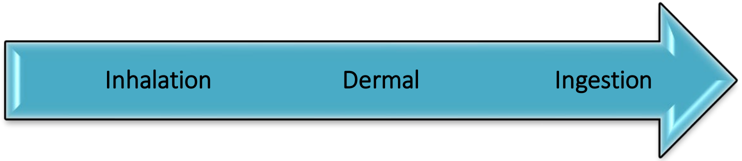
Note: NFPA ratings shown are for anhydrous hydrogen fluoride.
(NFPA, 2010)

Cameo Chemicals Link for More Information

HF: Symptoms via Different Routes of Exposure

- Eye Irritation
  - HF can penetrate the ocular tissues and produce severe damage to the eyes
  - Lacrimation, pain, and conjunctival injection are early symptoms
  - Corneal and conjunctival epithelium may be denuded, leading to edema and ischemia

- Respiratory Irritation
  - Concentrations as low as 5 ppm may produce irritation in the nasal mucosa
  - Mucosal edema, bronchospasm, bronchorrhea, wheezing, atelectasis, and airway obstruction
  - Onset of signs and symptoms may be immediate with death reported in as little as 30 minutes after exposure



Inhalation

Dermal

Ingestion

Most common Route of Exposure

Least Common Route of Exposure

- Dermal Exposure
  - Concentrations <20%: Redness (erythema), pain, and serious injury – possibly delayed for 24 hours after significant tissue injury

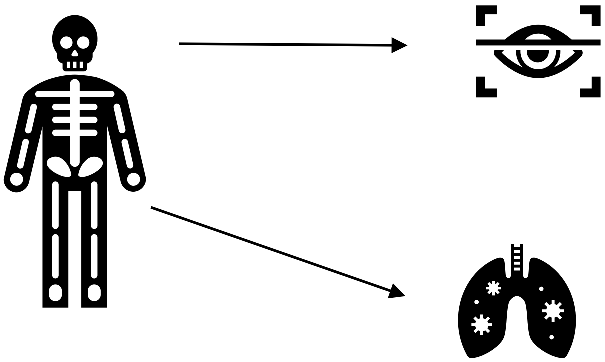
https://pubchem.ncbi.nlm.nih.gov/compound/14917#section=Skin-Eye-and-Respiratory-Irritations

HF: Acute Toxicity to Humans

- Can cause both severe burns and systemic toxicity
- Dehydration and corrosion of tissues and severe toxicity
- **Inhalation of HF causes coughing, choking, and lasting 1-2 hours after exposure**
- There may be an asymptomatic period of 1-2 days where pulmonary edema can occur with cough, chest tightness, (Dreisbach and Robertson, 1987)
- Severe irritation to eyes and respiratory tract, tearing, sore throat, cough, lower airway inflammation, and possible airway swelling (Wing *et al.* (1991)

https://oehha.ca.gov/media/downloads/crnr/appendixd2final.pdf

HF: Acute Toxicity to Humans



https://oehha.ca.gov/media/downloads/crnr/appendixd2final.pdf

Objective:

- Lund *et al*. 1997 study investigated eye and airway symptoms and lung function during and after 1 hour of exposure
- 20 healthy male volunteers were exposed to HF concentrations ranging from 0.2 to 5.2 mg/m3 (these are common exposures in aluminum industry)
- They were to report itching and soreness of the eyes

Results:

- Lower airway scores were not significantly different for any concentration range
- However, the upper airway was significantly increased at both the end of the highest exposure range (2.5-5.2 mg/m^3 and all exposures
  - Significantly correlated with HF concentration
  - The 0.7-2.4 mg/m3 range was considered a NOAEL

HF: Emergency, Occupational, and Health Guidance Levels

Emergency Exposure Levels

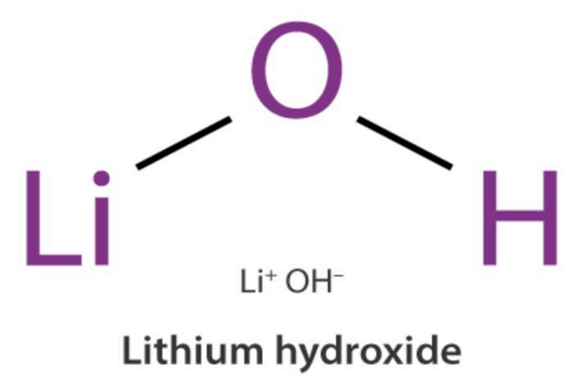
Type	Value(ppm)
AEGL-1 10 minutes	1 ppm
AEGL-2 10 minutes	95 ppm
AEGL-3 10 minutes	170 ppm
ERPG-1	2 ppm
ERPG-2	20 ppm
ERPG-3	50 ppm
PAC-1	1 ppm
PAC-2	24 ppm
PAC-3	44 ppm

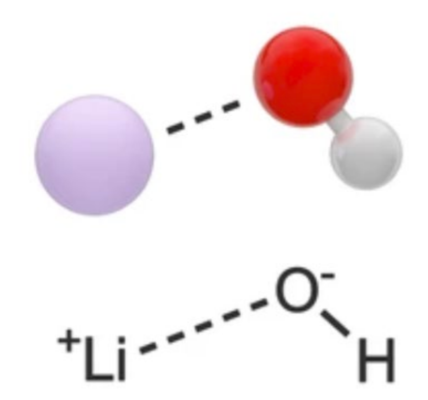
Health Guidance Value
OEHHA Acute Reference Exposure Level = 0.3 ppm

Occupational Exposure Levels

Type	Value (ppm)
NIOSH IDLH	30 ppm
NIOSH REL TWA	3 ppm
OSHA PEL TWA	3 ppm

CAMEO Chemicals, NIOSH Pocket Guide to Chemical Hazards, OEHHA, 2025





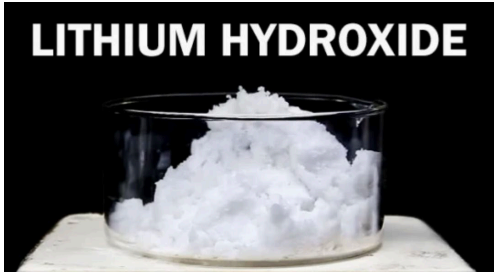
Lithium Hydroxide (LiOH)

CAS #: 1310-66-3

https://byjus.com/chemistry/lithium-hydroxide/

https://www.shutterstock.com/image-illustration/lithium-hydroxide-inorganic-compound-formula-lioh-1074288509

Physical and Chemical Properties of LiOH



- **Contact may cause severe irritation to skin, and eyes and is toxic by inhalation**

Chemical Formula	LiOH
Molecular Weight	24.0 g/mol
Melting point	450-471 °C
Density	2.54 g/cm
Vapor pressure	Pa at 20°C
Decomposition	924 °C

Cameo Chemicals Link for More Information

Pictogram(s)

Corrosive Acute Toxic Irritant

Signal

Danger

https://yujianghuagong.en.made-in-china.com/product/mnIrCFpTXXhw/China-Good-Price-Lioh-H2O-3-Monohydrate-Lithium-Hydroxide-for-Grease.html

LiOH: Fire and Explosion Hazard

Explosion and Reactivity:

- Reacts with certain metals (such as aluminum and zinc) to form oxides or hydroxides
- Reacts when heated above 84°C with aqueous solutions of reducing sugars to evolve toxic levels of carbon monoxide
- Heat of dissolution may generate steam and cause spattering

https://cameochemicals.noaa.gov/chemical/3770

https://pubchem.ncbi.nlm.nih.gov/compound/Lithium-Hydroxide#section=GHS-Classification

LiOH: Symptoms via Different Routes of Exposure

Inhalation Symptoms:

- Cough
- Sore throat
- Burning sensation
- Shortness of breath
- Labored breathing

Skin symptoms:

- Redness
- Serious skin burns
- Blisters

Eye Symptoms:

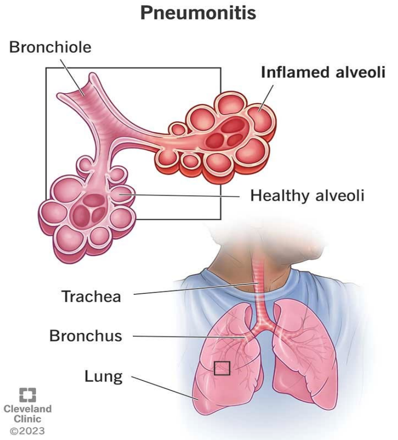
- Redness
- Blurred vision
- Severe deep burns

Ingestion Symptoms:

- Abdominal pain
- Burning sensation in the throat and best
- Nausea
- Vomiting

LiOH: Symptoms via Different Routes of Exposure

- Substance is corrosive to the eyes, skin, and respiratory tract
- Inhalation may cause long-term pulmonary swelling, but only after initial corrosive effects on eyes or airways

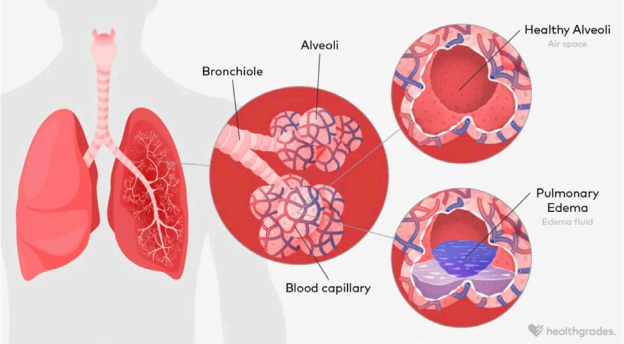


https://my.clevelandclinic.org/health/diseases/24810-pneumonitis

- **Neurotoxin**
- **Occupational hepatotoxin** (liver)
- **Nephrotoxin –** the chemical is potentially toxic to the kidneys
- **Dermatoxin –** skin burns
- **Toxic Pneumonitis –** inflammation of the lungs induced by inhalation of metal fumes or toxic gases and vapors

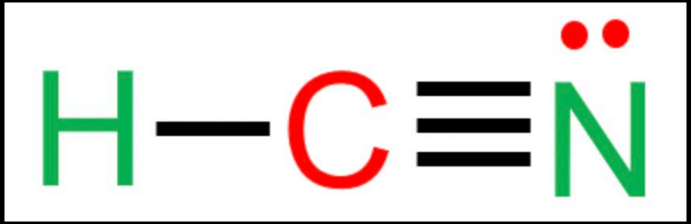
LiOH: Short-term (Acute) Health Effects

- Contact can severely irritate and burn the skin and eyes leading to eye damage
- Breathing Lithium Hydroxide Monohydrate can irritate the nose and throat
- Breathing Lithium Hydroxide Monohydrate can irritate the lungs causing coughing or shortness of breath
    - Higher exposures can build up fluid in the lungs --> pulmonary edema



https://nj.gov/health/eoh/rtkweb/documents/fs/1128.pdf

https://www.healthgrades.com/right-care/lungs-breathing-and-respiration/pulmonary-edema



Hydrogen Cyanide (HCN)

CAS #: 74-90-8

https://byjus.com/chemistry/hydrocyanic-acid/

HCN: Fire and Explosion Hazard

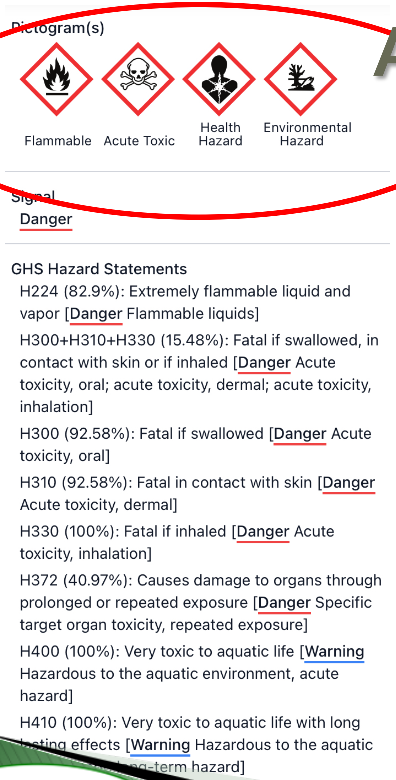
Fire hazard
- Combustible material; may burn but does not ignite readily
- Containers may explode when heated
- Runoff may pollute waterways

Cameo Chemicals Link →

Explosion hazard
- Highly flammable but absorption can prevent evolution of enough vapors to ignite readily
- Reacts as an oxidizing agent and as a weak acid
- Presents an explosion hazard when heated or exposed to oxidizing agents
- Reacts violently with acetaldehyde
- May polymerize in the presence of traces of alkali or at elevated temperatures

https://cameochemicals.noaa.gov/chemical/3614

HCN: Globally Harmonized System (GHS) Classifications & National Fire Protection Association (NFPA) 704 Signal



Signal
Danger

GHS Hazard Statements

H224 (82.9%): Extremely flammable liquid and vapor [Danger Flammable liquids]

H300+H310+H330 (15.48%): Fatal if swallowed, in contact with skin or if inhaled [Danger Acute toxicity, oral; acute toxicity, dermal; acute toxicity, inhalation]

H300 (92.58%): Fatal if swallowed [Danger Acute toxicity, oral]

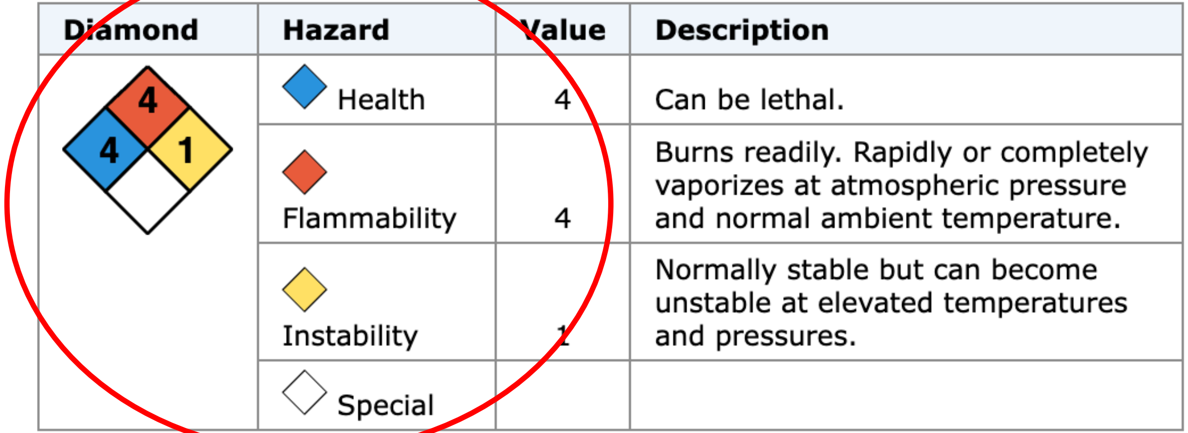
H310 (92.58%): Fatal in contact with skin [Danger Acute toxicity, dermal]

H330 (100%): Fatal if inhaled [Danger Acute toxicity, inhalation]

H372 (40.97%): Causes damage to organs through prolonged or repeated exposure [Danger Specific target organ toxicity, repeated exposure]

H400 (100%): Very toxic to aquatic life [Warning Hazardous to the aquatic environment, acute hazard]

H410 (100%): Very toxic to aquatic life with long lasting effects [Warning Hazardous to the aquatic long-term hazard]



Diamond	Hazard	Value	Description
4 / 4 / 1	◆ Health	4	Can be lethal.
	◆ Flammability	4	Burns readily. Rapidly or completely vaporizes at atmospheric pressure and normal ambient temperature.
	◆ Instability	1	Normally stable but can become unstable at elevated temperatures and pressures.
	◇ Special		

(NFPA, 2010)

https://pubchem.ncbi.nlm.nih.gov/compound/768#section=GHS-Classification

HCN: Symptoms via Different Routes of Exposure

Inhalation Exposure

- Confusion, drowsiness, headache, nausea, shortness of breath, convulsions, unconsciousness, respiratory and cardiac arrest

Skin Exposure

- May be absorbed

Ingestion Exposure

- Burning sensation
- Asphyxia, lassitude (weakness, exhaustion), headache, confusion, nausea

Target organs: central nervous system, cardiovascular system, thyroid, blood

Symptoms of Acute Hydrocyanic Acid Exposure:

- Hypertension (high blood pressure)
- Tachycardia (rapid heart rate) followed by hypotension (low blood pressure) and bradycardia (slow heart rate)
- Cardiac arrhythmias and other cardiac abnormalities are common

https://pubchem.ncbi.nlm.nih.gov/compound/768#section=Target-Organs

Emergency, Occupational, and Health Guidance Levels

Emergency Exposure Levels

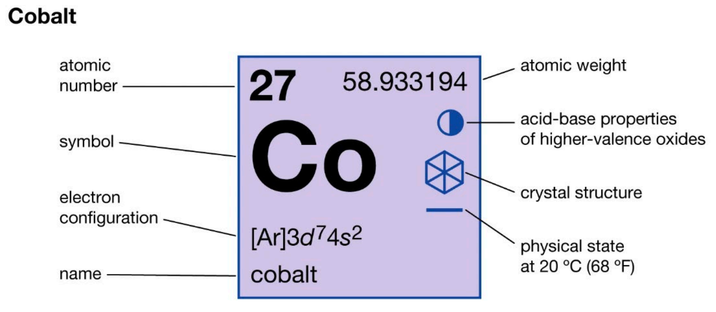
Type	Value (ppm)
AEGL-1 10 min	2.5 ppm
AEGL-2 10 min	17 ppm
AEGL-3 10 min	27 ppm
PAC-1	2 ppm
PAC-2	7.1 ppm
PAC-3	15 ppm
ERPG-1	N/A
ERPG-2	10 ppm
ERPG-3	25 ppm

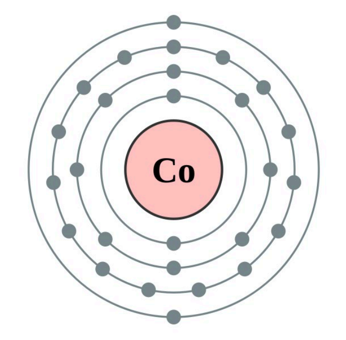
Source: CAMEO Chemicals

Occupational Exposure Levels

Type	Value (ppm)
NIOSH IDLH	50 ppm
NIOSH REL	4.7 ppm
OSHA PEL TWA	10 ppm

Source: NIOSH Pocket Guide to Chemical Hazards





Cobalt (Co)

CAS #: 7440-48-4

https://periodictable.me/cobalt-valence-electrons/

https://www.britannica.com/science/cobalt-chemical-element

Physical and Chemical Properties

Physical Properties:

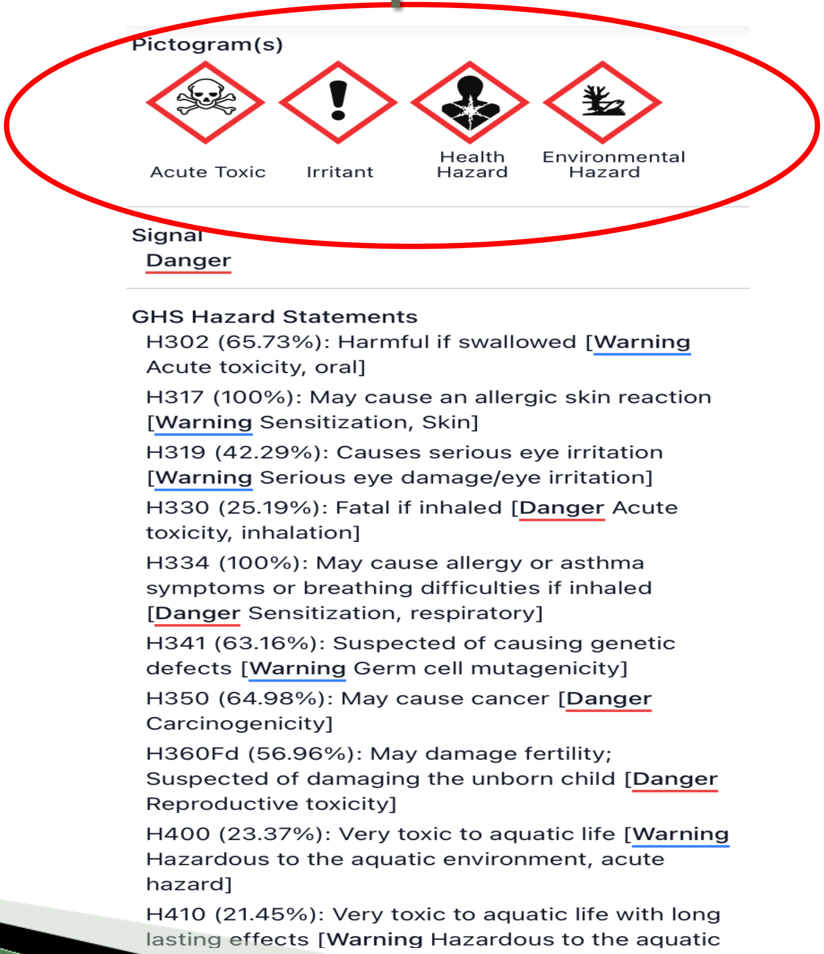
- Naturally occurring elements found in rocks, soil, water, plants, and animals
- Used to produce alloys used in the manufacture of aircraft engines, magnets, grinding and cutting tools
- Silver-grey powder

Chemical Formula	Co
Molecular Weight	58.93319 g/mol
Melting point	-83.57 °C
Boiling point	2,9271°C
Melting Point	1,495°C
Density	8.9 g/cu m at 20°C
Vapor pressure	0 mmHg at 68°F
Stability/ Shelf Life	Stable under recommended storage conditions; corrodes readily in air
Decomposition	Hazardous decomposition products formed under fire conditions
Heat of Vaporization	6276 J/g

https://www.alamy.com/cobalt-chemical-element-atom-cobalt-symbol-periodic-table-image426854905.html

https://pubchem.ncbi.nlm.nih.gov/compound/104730#section=Decomposition

Fire and Explosion Hazard



Pictogram(s)

Acute Toxic

Irritant

Health Hazard

Environmental Hazard

Signal

Danger

GHS Hazard Statements

H302 (65.73%): Harmful if swallowed [Warning Acute toxicity, oral]

H317 (100%): May cause an allergic skin reaction [Warning Sensitization, Skin]

H319 (42.29%): Causes serious eye irritation [Warning Serious eye damage/eye irritation]

H330 (25.19%): Fatal if inhaled [Danger Acute toxicity, inhalation]

H334 (100%): May cause allergy or asthma symptoms or breathing difficulties if inhaled [Danger Sensitization, respiratory]

H341 (63.16%): Suspected of causing genetic defects [Warning Germ cell mutagenicity]

H350 (64.98%): May cause cancer [Danger Carcinogenicity]

H360Fd (56.96%): May damage fertility; Suspected of damaging the unborn child [Danger Reproductive toxicity]

H400 (23.37%): Very toxic to aquatic life [Warning Hazardous to the aquatic environment, acute hazard]

H410 (21.45%): Very toxic to aquatic life with long lasting effects [Warning Hazardous to the aquatic

Fire hazard

- Incompatibilities and reactivities with strong oxidizers and ammonium nitrate
- **Dust of this chemical is flammable**

Symptoms via Different Routes of Exposure

Inhalation Exposure

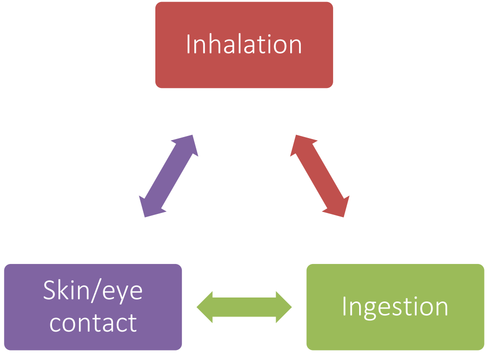
- Cough, dyspnea (breathing difficulty), wheezing, decreased pulmonary function, weight loss, dermatitis, diffuse nodular fibrosis, respiratory hypersensitivity, asthma
- Target organs: Skin, respiratory system

Skin

- Symptoms such as redness and irritation can develop

Ingestion

- Some heavy metals are very toxic poisons, especially if their salts are soluble in water
- Abdominal pain and vomiting



Inhalation

Skin/eye contact

Ingestion

Acute Toxicity to Humans

- Acute (short-term) exposure to high levels of cobalt by inhalation results in respiratory effects and a decrease in ventilatory function, congestion, edema, and hemorrhage of the lung
- Evidence from animal studies – cobalt inhalation causes pulmonary irritation, dose-dependent edema, and damage in lungs (Agency for Toxic Substances and Disease Registry, 2023)

Emergency, Occupational, and Health Guidance Levels

Emergency Exposure Levels

Type	Value
PAC-1	0.06 mg/m3
PAC-2	2 mg/m3
PAC-3	20 mg/m3

Source: CAMEO Chemicals

Occupational Exposure Levels

Type	Value
NIOSH IDLH	20 mg/m3
NIOSH REL TWA	0.05 mg/m3
OSHA PEL TWA	0.1 mg/m3

Source: NIOSH Pocket Guide to Chemical Hazards

Type	Value
US EPA RSL Air	6.3 mg/m^3

https://www.cdc.gov/niosh/idlh/7440484.html

Hazards and Safety Guidelines

27th California Unified Program
Annual Training Conference
March 24-27, 2025

Hazards and safety guidelines

- **Thermal Runaway:** When batteries overheat, a chain reaction leads to self-sustaining combustion.
- **Overcharging or Improper Charging:** Using non-manufacturer-approved chargers or charging near flammable materials can increase risks.
- **Physical Damage:** Dropped or punctured batteries can ignite due to internal short circuits.
- **Improper Disposal:** Discarding batteries in regular trash or recycling bins has led to multiple garbage truck and recycling plant fires.

Hazards and safety guidelines

1. **Charge Safely:** Use manufacturer-approved chargers and avoid overcharging.
2. **Store Properly:** Keep batteries away from direct sunlight, heat sources, and flammable materials.
3. **Dispose Responsibly:** Use designated hazardous waste facilities for battery disposal.
4. **Monitor for Warning Signs:** If a battery is hissing, swelling, or emitting smoke, move it away from structures and call emergency services.
5. **Limit Indoor Storage:** Businesses handling large numbers of lithium-ion batteries should have fire suppression systems in place.

Emergency Response and Cleanup after an LIB Fire

What is needed? Identifying gaps and best practices

- Additional Field studies
- Standard Operating Procedure (SOPs) and Best Practices
- Safe Cleanup, Removal, and Transport guidance
  - Chemicals may be emitted during transport or in landfills after disposal if reignition occurs
- Education
  - Public/Community Education
  - First Responders and Hazmat Firefighters
  - Cleanup Workers
  - Environmental and public health officials

A large-scale incident has occurred, what do you do?

1. **Pre-incident Preparedness:**
   - Site assessments
   - Training and drills
   - Regulatory knowledge
2. **Initial Response Actions:**
   - Assess the scene
   - Declare hazmat incident early, contact US EPA On-Scene Coordinator (OSC)
   - Establish safety parameters
3. **Managing the fire**
   - Prepare for the possibility of reignition
   - Chemicals may be emitted during transport or in landfills after disposal, if reignited
   - Ventilate the structure
   - Control water use

Source: The Camino Incident: https://www.usfa.fema.gov/podcasts/episode-38/

A large-scale incident has occurred, what do you do?

4. **Incident Mitigation & Containment**
    - Engage experts, manufacturer, etc.
    - Put monitoring and sampling plans in place
    - Manage runoff water
    - Fire suppression strategy
    - Pre-plan staging areas
    - Messaging to the public
    - Initiate cleanup plans (de-linking, de-energizing, staging, disposal)
    - Pre-identify where waste will be accepted
5. **Post-incident Recovery:**
    - Coordinate with property owners
    - Short and long-term environmental monitoring
    - Education – public education, fire responders, cleanup workers

Source: The Camino Incident: https://www.usfa.fema.gov/podcasts/episode-38/

A large-scale incident has occurred, what do you do?

6. Consider forming a Multi-Agency Coordination Group (MAC-g)

- Consider forming a MAC-g of subject matter experts (SMEs) to assist:
  - Data review (air, soil, water, etc.)
  - Public Health messaging
  - Review monitoring, sampling, cleanup plans

Air Monitoring

- Deploy air monitoring equipment as fast as possible after the fire starts
  - At the site of the fire
  - Fence-line monitoring
  - Community monitoring
- Plume modeling is essential to know where to deploy monitors
- Mobile monitoring platforms
- Stationary air monitoring
- Deploy summa canisters following the plume if available
- Pre-plan inventory of air monitoring equipment and laboratories that will analyze data; involve US EPA, Air District, and CARB

Air Monitoring cont.

- Real-time air monitoring
  - Particulate matter (PM2.5 and PM10)
  - Carbon monoxide (CO)
  - Hydrogen fluoride (HF) as part of acid-gas mixture include:
    - Hydrogen cyanide
    - Hydrogen chloride
  - Metals extracted from PM filter
  - Summa canister (if available) for toxic air contaminants (plume model)

- Important to have:
  - Data Quality Objectives (DQOs)
  - Conceptual Site Model
  - Exposure scenarios
  - Analytical services
  - Availability of equipment
  - Familiarity with sensor networks
  - Close communication with RP and their contactor to coordinate data collection as quickly as possible.
  - Set-up a webpage to report out results and messaging

Air Monitoring cont.

- Evacuation/Shelter-In Place Orders
- Sensitive receptors (e.g. schools, hospitals, and parks)
- Ash and Debris
  - Where observed
  - A way for community to report
  - A plan to remove debris
  - A plan to sample ash and debris
  - Maps!!!
    - Sampling locations

Soil, Sand, Sediment and Surface Water

- US EPA, DTSC, OEHHA, CalRecycle
- Sampling Plan
- Map locations, take photos
- Discrete and duplicate samples (>1 per site)
- Understand background levels (USGS)
- Sensitive receptors (e.g. schools and parks)
- Analyze for at least PAHs and metals
- Asbestos
- Consider pre- and post- rain
- Ash and debris complaints

Additional Considerations

- Drinking water
  - Wells, well heads, groundwater impacts
  - Work with local water systems and Regional Water Quality Control Board (RWQCB)
- Biota, runoff, and ecological impacts
  - California Department of Fish and Wildlife (CDFW), National Oceanic Atmospheric Administration (NOAA), State of CA Waterboard
  - Recreational areas
  - Take special note of where children may visit
  - Retention ponds, stormwater runoff, fire suppressant collection: testing
  - PAHs, dioxins/furans, metals

Cleanup Plans

- Make sure your facilities have an emergency plan!
- Work with the responsible party on a cleanup plan
- Key decisions on staging of debris
- De-linking and de-energizing of batteries
- Transportation and disposal
- Managing debris in the community

In Summary: LIBs: from E-scooters to BESS

- Identify and understand all high-hazard sites in your jurisdiction.
- Conduct thorough preplanning for potential incidents.
- Consult with experts and companies that manage these hazards.
- Acknowledge that these incidents can and do occur.
- Recognize the fire department's responsibility in managing such emergencies.
- Plan for the worst possible outcomes to ensure preparedness.
- Stay ahead by proactively preplanning to simplify incident response.

"Lithium-ion Batteries: It's Not a Matter of IF but WHEN"

Art by Paul Combs

https://www.fireengineering.com/firefighting/drawn-by-fire-not-your-old-dragon/

ReCap

- Short introduction to Lithium-Ion Batteries (LIBs)
- Diversity in type and size of products w/ LIBs
- Incidents, injuries, and hospitalizations
- Chamber studies on emissions
  - Chemicals, exposure, and health and safety
- Emergency response and cleanup
  - Air, soil, surface water, drinking water, biota, runoff

Thank you!

27th California Unified Program
Annual Training Conference
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Any Questions?

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