Info Sheet

PFAS in Electric Vehicle Batteries

What is PFAS?

Per- and polyfluorinated alkyl substances (PFAS) — also referred to as 'forever chemicals' — are a family of over 10,000[1] highly fluorinated human-made substances. Since the 1940s, PFAS have been used in an estimated 1,400 different products and processes[2] from non-stick cookware, food packaging, fire-fighting foams to weatherproof garments, as well as industrial applications in electronics, aviation, oil production, and mining. These chemicals also cause pollution at every stage of production.

Sources of PFAS pollution include PFAS chemical manufacturing facilities, landfills, airports, military bases, and wastewater treatment plants, which often contaminate the air, water, and soil of the surrounding environment and are disproportionately located near watersheds serving low-income communities and communities of color.[3] According to a study conducted by researchers at the Harvard School of Public Health, Black and Hispanic communities are more likely to have PFAS in their drinking water compared to other groups.[4] Their unique resistance to grease, oil, water, and heat comes from a carbon-fluorine bond, which results not only in exceptional durability but also undesirable persistence in the environment, including in the air, water, and soil.

While only a fraction of PFAS have been thoroughly studied for their environmental health impacts, existing evidence shows that exposure to PFAS can be endocrine disruptors, reprotoxic, immunotoxic, and carcinogenic.[5]

PFAS in Electric Vehicle Batteries

Today, most electric vehicles use lithium-ion batteries (LIBs),[6] which all rely on the use of PFAS in manufacturing certain components, including binders, separators, and electrolytes.[7] Over 40 percent of the polyvinylidene difluoride (PVDF) manufactured globally is used in EV batteries, with global production of PVDF expected to double by 2028.[8] This is because many PFAS contain a unique set of properties that can improve the performance of these battery components. A subset of PFAS, fluoropolymers such as PVDF are the most frequently used material in binders[9] as they offer higher stability and help prevent self-discharge by inhibiting some electrochemical reactions, thereby improving the energy density and lifespan of the battery.[10]

The battery separator[11] uses fluoropolymers, including PVDF, to obtain high polarity, stable electrochemical performance, strong tensile properties, and favorable thermal stability. Fluorinated electrolyte[12] salts such as LiPF6, the main electrolyte salt used in commercial

1 European Chemicals Agency. "ECHA publishes PFAS restriction proposal." https://echa.europa.eu/it/-/echa-publishes-pfas-restriction-proposal.

2 Rensmo, Amanda et al. 2023. "Lithium-Ion Battery Recycling: A Source of per- and Polyfluoroalkyl Substances (PFAS) to the Environment?" Environmental Science: Processes & Impacts 25 (6): 1015–30.

3 "Sociodemographic Factors Are Associated with the Abundance of PFAS Sources and Detection in U.S. Community Water Systems, Environmental Science & Technology.

4 Ibid.

5 Chemtrust. 2019. "PFAS the 'Forever Chemicals'"

6 Mills, Ryan. 2023. "EV Batteries 101: The Basics." RMI. March 8, 2023. EV Batteries 101: The Basics.

7 Zvei. 2023. Factsheet "PFAS in Batteries"

8 Welch, Craig et al. July 10, 2024. Forever chemical' polluters land hefty contracts to meet electric vehicle battery demand". The examination.

9 Binders are used to bind the active material (the chemically active components of the cathode and anode and the electrolyte between them), conductive agent, and current collector together to facilitate the electrochemical reactions necessary to deliver electrical energy. Morneau, Chappell. 2020. Lithium-Ion Batteries : Properties, Advantages and Limitations. New York: Nova Science Publishers, 2.

10 Rensmo, Amanda et al. 2023. "Lithium-Ion Battery Recycling: A Source of per- and Polyfluoroalkyl Substances (PFAS) to the Environment?" Environmental Science: Processes & Impacts 25 (6): 1015–30.

11 A semi-permeable barrier separating the two electrodes (cathode and anode) to prevent electrical contact between them.

12 Electrolyte is stored within the separator and is used as a medium - often in the form of a liquid or gel - to allow for the transfer of lithium-ions back and forth between the anode and cathode.

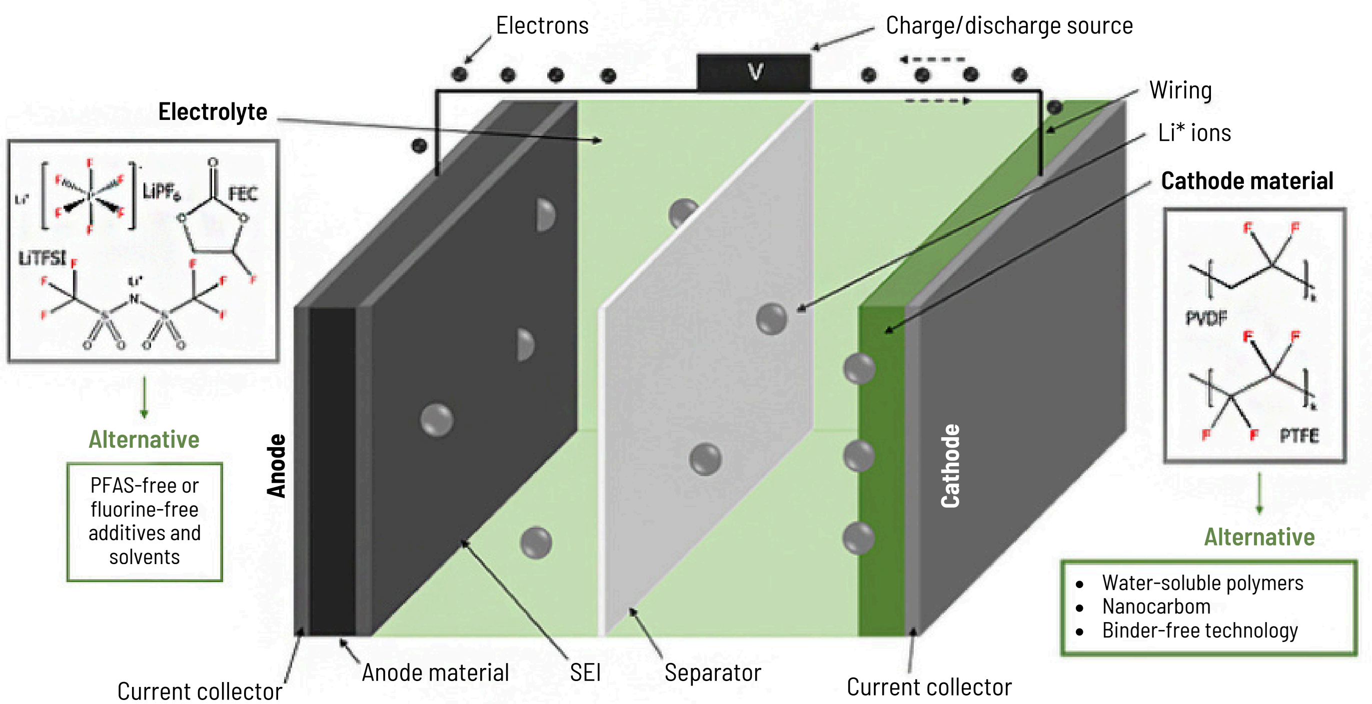

Figure 1: *Schematic structure of a lithium-ion battery cell highlighting the components where PFAS (and other fluorinated substances) are used to the largest extent (with given example structures) and alternatives are needed. Source: "PFAS-Free Energy Storage: Investigating Alternatives for Lithium-Ion Batteries." By Savvidou, E. et al. 2024. https://pubs.acs.org/doi/10.1021/acs.est.4c06083.*

batteries, are commonly used for their high ionic conductivity. Similarly, fluorinated additives such as LiFSI (often used together with LiPF6) play a vital role in improving conductivity and flame retardance and reducing gas build-up within the LIB cells.

PFAS are also emitted during the LIB recycling process. During the pre-treatment phase of hydrometallurgical recycling, a process that uses chemical-treated water to extract valuable metals from a feedstock, the spent batteries go through thermal treatment at temperatures around 160 °C to deactivate the battery. The relatively low temperature may lead to an incomplete breakdown of PFAS in addition to the production and release of new and persistent fluorinated substances.[13]

While some researchers suggest it is technically feasible to develop PFAS-free binder materials for batteries,[14] no viable industry-wide alternatives currently exist[15] and promising replacements are unlikely to emerge on a commercial scale in the near future.[16] The manufacturing and recycling of EV batteries therefore present significant risk of PFAS exposure to facility workers and surrounding communities.

PFAS Regulations

In the EU, current PFAS legislation has placed restrictions on perfluorooctane sulfonate (PFOS) and a ban on perfluorooctanoic acid (PFOA), two widely used PFAS.[17,18] In the Asia Pacific, China has banned the export and import of certain PFOS products[19] and set detection limits of PFOA and PFOS in textile products[20] while South Korea has restricted the production, import/export, and use of PFOS under its Persistent Organic Pollutants (POPs) Control Act.[21] India on the other hand has yet to establish regulations or monitoring programs.[22] The European Union, China, South Korea, and India have all ratified and agreed to enter into force the Stockholm Convention on Persistent Organic

13 Rensmo, Amanda et al. 2023. "Lithium-Ion Battery Recycling: A Source of per- and Polyfluoroalkyl Substances (PFAS) to the Environment?" Environmental Science: Processes & Impacts 25 (6): 1015–30.

14 Savvidou, Eleni K. et al. 2024. "PFAS-Free Energy Storage: Investigating Alternatives for Lithium-Ion Batteries." Environmental Science & Technology 58 (50): 21908–17.

15 Researchers are currently working to develop PFAS-free alternatives for binder materials.

16 Ibid.

17 PFOA and PFOS are commonly found in aqueous film-forming foam (AFFF), a type of firefighting foam used to put out flammable liquid. PFOA and PFOS are also used for other purposes such as nonstick coating on cookware and surface protection products.

18 "Sostanze Per- e Polifluoroalchiliche (PFAS) - ECHA." 2025. Sostanze per- e polifluoroalchiliche (PFAS).

19 China to Prohibit the Import and Export of PFOS Products in 2024." January 5, 2024. http://www.cirs-group.com/en/chemicals/china-to-prohibit-the-import-and-export-of-pfos-products-in-2024.

20 "Further Research on PFAS Pollution in China – PFAS Concentrations in the Environment, PFAS Policies, and Their Impacts – Sino-German Environmental Partnership."

21 National Implementation Plan for the Stockholm Convention

22 Koulini, G. V. et al. 2024. "Per- and Polyfluoroalkyl Substances in Indian Environment: Prevalence, Impacts and Solutions." Journal of Water Process Engineering 66 (September):105988. https://doi.org/10.1016/j.jwpe.2024.105988.

Pollutants (POPs), a multilateral treaty that requires parties to take measures to eliminate or reduce the release of POPs into the environment.[23]

The United States, however, is one of the only few countries in the world that has yet to ratify the Convention.[24] Nonetheless, in 2021, the U.S. Environmental Protection Agency (EPA) released their PFAS Strategic Roadmap, outlining how it would curtail PFAS contamination in the country.[25] In April 2024, the EPA designated PFOA and PFOS as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which would make it easier to mandate their removal from the environment.[26] Unfortunately, this designation can further exacerbate environmental injustices by promoting the incineration of PFAS at commercial incinerators that are predominantly found in Black communities.[27]

There are also still thousands of PFAS chemicals in use, and with so many different types of PFAS available, businesses can routinely swap out old PFAS for new ones in response to new regulations, or when they are better suited to their needs.[28] This process of "regrettable substitution" – switching out one hazardous substance with another[29] – is evident in the practices of Solvay Specialty Polymers, a chemical company that produces PVDF. By the time the company completely phased out the use of PFNA – another type of PFAS – in 2010, it had already been releasing hundreds of thousands of pounds of other forever chemicals that may be just as toxic.[30] More recently, emerging LIB technologies have been using a particular subclass of PFAS called bis-perfluoroalkyl sulfonimides (bis-FASIs), which are "not currently regulated anywhere in the world."[31]

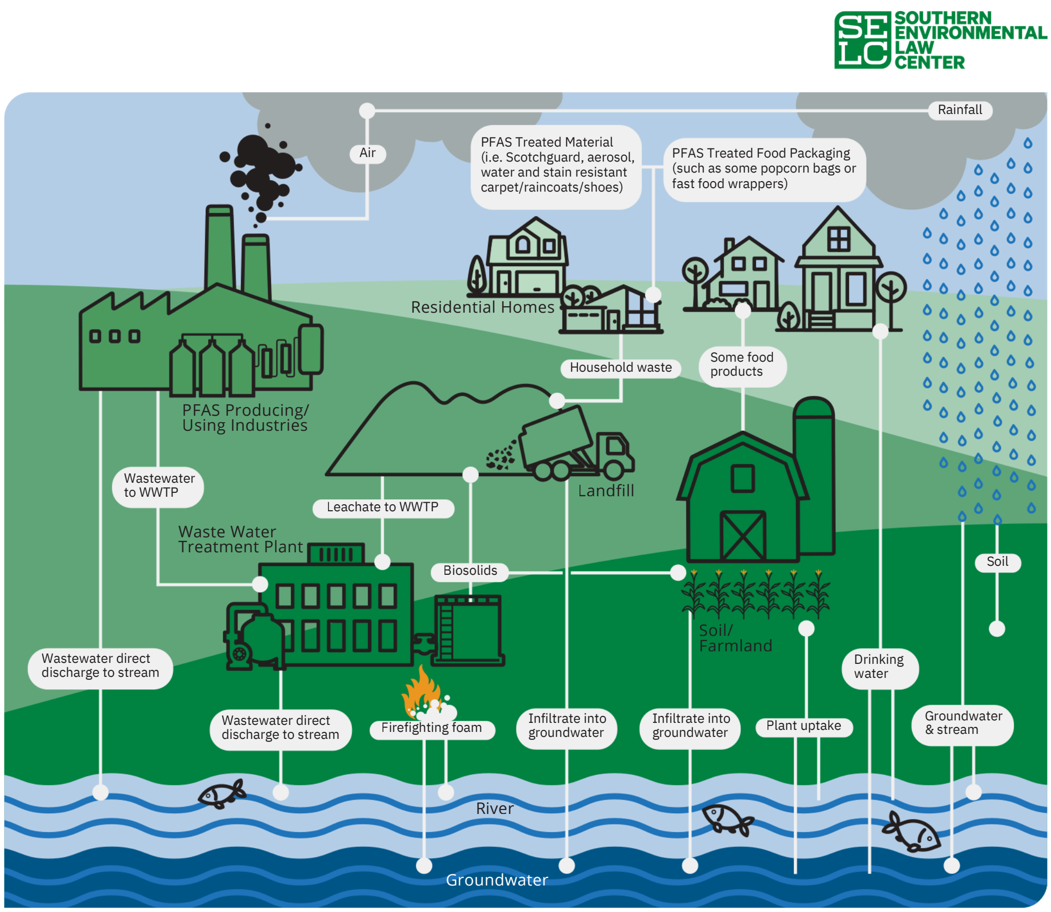

Figure 2: *PFAS Cycle. Source: Southern Environmental Law Center.*

23 Stockholm Convention on Persistent Organic Pollutants (POPs)

24 Notable non-ratifying states also include Israel and Malaysia.

25 U.S. EPA. PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024

26 U.S. EPA. Biden-Harris Administration Finalizes Critical Rule to Clean up PFAS Contamination to Protect Public Health.

27 "An EPA Plan to Curb Pollution Could Dump More of It Into Black Neighborhoods." 2024. In These Times. May 28, 2024. https://inthesetimes.com/article/epa-pfas-forever-chemicals-disposal-environmental-justice.

28 Welch, Craig et al. July 10, 2024. Forever chemical' polluters land hefty contracts to meet electric vehicle battery demand". The examination.

29 European Environment Agency. "Chemicals Signals."

30 "Solvay Workers Found to Have Unregulated PFAS in Their Blood, Documents Show." 2020. Consumer Reports.

31 Lithium-Ion Battery Components Are at the Nexus of Sustainable Energy and Environmental Release of per- and Polyfluoroalkyl Substances. Nature Communications." https://www.nature.com/articles/s41467-024-49753-5.

Recommendations

One of the key ways to mitigate the harms of PFAS is through investing in and scaling up new technologies that (1) eliminate or greatly reduce PFAS in battery manufacturing and (2) allow removal of binders, separators, electrolytes or other PFAS-laced battery components without the release of PFAS into the environment. Although some of these greener substitutes and techniques have been developed and proven to be successful in laboratory settings,[32,33] they have yet to be commercially scaled and demonstrate their ability to meet required performance standards.[34] The use of artificial intelligence (AI), however, shows great potential in accelerating the discovery and development of safer materials.[35]

Nonetheless, while these new technologies are in the process of being scaled up for industry use, manufacturers of PFAS-containing products or product components must disclose PFAS use and entrust stakeholders to safely manage it through the life cycle. At EV battery recycling facilities, the names and amounts of PFAS being released throughout various processes should be properly monitored and reported. Details of names and amounts of PFAS compounds used in the products should be registered to a publicly accessible data collection interface, regulated by environmental authorities. This data can then be used to help take steps to protect public health and safety by advocating for standards and regulations that require reduced emissions and exposures.

32 Kamczyc, Alex. 2023. "Researchers Develop Nontoxic, Recyclable Binder for Batteries." Recycling Today. https://www.recyclingtoday.com/news/researchers-develop-nontoxic-recyclable0binder-batteries-lawrence-berkley.

33 "Green Method for Binder Recovery from Lithium-Ion Battery Electrodes." The Faraday Institution. https://www.faraday.ac.uk/success-stories/green-method-for-binder-recovery.

34 Welch, Craig et al. July 10, 2024. Forever chemical' polluters land hefty contracts to meet electric vehicle battery demand". The examination.

35 Vecellio, Emma. 2024. UB researcher co-founds venture to revolutionize companies' materials usage. UBNow. https://www.buffalo.edu/ubnow/stories/2024/10/rajan-materials-in.html.

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