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Power Failure: The Battered Legacy of Leaded Batteries

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The history of automobiles is inextricable from the story of one of the most pervasive toxic chemical exposures in modern human history. Globally, billions of people[1] were poisoned by lead (Pb) between 1921, when *General Motors Corporation* introduced tetraethyl lead as an antiknock agent in gasoline-powered cars, until 2015, when leaded gasoline was scheduled to be phased out in Algeria, the last country still using leaded gasoline.

The elimination of lead from gasoline is one of the greatest milestones in public health. Regulatory policies were instrumental in achieving the phase-out of leaded gasoline, and these were informed by incontrovertible scientific evidence that there are no safe levels of exposure to lead and that children are particularly susceptible to its adverse health effects.[1] Unfortunately, lead remains a tenacious toxicant because of ubiquitous lead-acid batteries that power more than a billion cars on the road today.

A FAILED POLICY ON RECYCLING

In 2015, ~90% of 1.62 million tons of lead consumed in the United States was for production of >94.1 million lead-acid batteries.[2] These batteries have an international life cycle: during the first 8 months of 2015, 19.3 million spent lead-acid batteries, containing an estimated 167 000 tons of lead,[2] were exported to low- and middle income countries where they fed hazardous industries for materials recovery.

Spent lead-acid batteries are recognized as hazardous waste under Annex VIII of the United Nation's Basel Convention on the Control of Transboundary Hazardous Wastes and Their Disposal.[3] However, several loopholes keep the international flow of toxic products intact. The U.S. has not ratified the Basel Convention. Rather, lead-acid batteries are regulated under the Resource Conservation and Recovery Act (RCRA) of 1976, as part of negotiations to harmonize U.S. policies with initiatives of the Organization for Economic Cooperation and Development.[4]

Individual states in the U.S. stipulate either mandatory or voluntary cash deposits, typically $5−10, for used batteries returned by consumers at the point of purchase of a new lead-acid battery. The U.S. Environmental Protection Agency (EPA) considers the high "recycling" rate of lead-acid battery as evidence of successful public-private partnerships in pollution prevention policy.[4]

The apparent success of the retailer take-back program masked growing concerns about pollution and health impacts created by battery recycling in developing countries, until similar problems emerged within continental U.S., exemplified by a recent case in California. In February, 2016, California Governor Jerry Brown proposed spending $176.6 million to accelerate the testing and cleanup of thousands of lead-contaminated homes surrounding the troubled Exide battery recycling facility in the Vernon district of Los Angeles, which is predominantly populated by families in the lower socio-economic category.[5] The funds will support testing 10 000 homes within 1.7 miles of the closed facility and the removal of lead-contaminated soil from about 2500 homes where levels pose the greatest risk of poisoning.[5]

Unfortunately, the Exide-linked pollution in Los Angeles is only a "tip of the iceberg" in terms of global impacts of lead poisoning from batteries. The international market for reclaiming lead is growing rapidly,[2] and battery-recycling operations can be found in almost every city in the developing world. Battery smelting operations are often located in densely populated areas with inadequate pollution controls. Regulatory policies that supported high rates of battery recycling also dampened interest in developing safer lead-free alternatives. The emergence of hybrid and full electric automobiles has spurred the development of advanced lithium-ion batteries, but these may have their own safety concerns.

EMPOWERING INNOVATION

California's landmark Safer Consumer Products Law of 2013 requires manufacturers to seek safer alternatives to harmful chemical ingredients in widely used products. At the federal level, the U.S. EPA uses alternatives analysis (AA) as part of chemical action plans in its chemical management program. Similarly, the European Union's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) program imposes alternatives analysis obligations upon certain partic-

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ularly dangerous listed chemicals. The paradigm shift from risk management to risk prevention will require manufacturers to fundamentally alter the way they design and make automobile batteries. This prevention-based approach raises three interrelated research challenges for adopting safer alternatives to lead-acid batteries:

First, there is a need for deeper understanding of the relative toxicity of assembled products. Adoption of AA exacerbates the challenges presented by conventional risk assessment by shifting the focus from known toxicants to lesser known potential replacement chemicals. Predictive toxicology, with its computational approaches and high throughput assays, offers a potential solution to this dilemma, but research to integrate computational materials synthesis and computational toxicology into a comprehensive informatics framework is underdeveloped, and needs infusion of ideas and resources.[6]

Second, the current regulatory policy that emphasizes collection and recycling of lead-acid batteries discounts the cumulative impacts across the entire life cycle of the batteries, from mining raw materials to the useful life of the products to disposal or recovery of reusable materials. Product life cycle analyses (LCA) go beyond the properties and impacts of individual chemical or material constituents of the finished battery, and must include the impacts of mining and physical treatments used in manufacturing or recycling. The large number of objective variables and subjective weights assigned to different impacts that products may have on environmental quality and human health have proved daunting for traditional LCA research. Research to integrate computational scenario-based projections into existing LCA models and databases should be explored to advance the development of comprehensive, data-transparent, and realistic product LCA.

Finally, research on multicriteria decision analysis tools to support manufacturers and regulatory agencies should be expanded beyond the typical consideration of technical performance and economic feasibility of new battery designs. In some cases, the data on additional criteria will be incomplete or presented with wide margins of error.[7] Innovative research approaches are needed to develop realistic projections for decision impact analysis. Selecting among alternative materials for new battery designs will present value judgments in identifying the best combination of trade-offs. Transparency of decision-making process, including consideration of any and all potential health and environmental impacts in communities near and far will reduce the tendency to be complacent with narrowly defined measures of materials sustainability, such as defunct-product collection and recycling rates.

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Notes

The author declares no competing financial interest.

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