Sociotechnical Synthesis

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Recycling Risk: A Sociotechnical Analysis of the Environmental Injustice in Battery Recycling

"In Chemical Process Safety, what you don't know won't hurt you. It will kill you."
- Prof. Ronald Unnerstall

As the United States pushes forward with the electrification of its energy economy—especially through the widespread adoption of electric vehicles—the demand for lithium-ion batteries has surged. This rapid growth brings with it a pressing need to sustainably manage spent lithium-ion batteries (SLIBs). Battery recycling plants have emerged as essential infrastructure to support a circular battery economy, but they often pose significant health and environmental risks to the communities around them—particularly those that are already vulnerable or politically marginalized. With increasing reports of garbage trucks and recycling plants catching fire, exploding, or releasing contaminated water into rivers, the battery recycling industry risks becoming viewed as "too dangerous to be worth it," mirroring the fate of the nuclear energy sector in the public eye after the Fukushima disaster. Acknowledging both the technical and social dimensions of this problem, I pursued a two-part thesis project: one focused on the design and safety analysis of hydrometallurgical recycling systems, and the other on exploring the social, political, and ethical consequences of battery recycling through the lens of Science, Technology, and Society (STS). My goal was to identify how battery recycling can become safer—and avoid following the path of nuclear energy.

In my STS research, I examined how battery recycling plants disproportionately affect surrounding communities, particularly those lacking political influence. Using Actor-Network

Theory (ANT), I mapped the relationships among key stakeholders: local residents, plant operators, government agencies, and the environment. I found that companies operating these plants often exert significant influence over local governments by leveraging their economic impact—especially through job creation—to resist the implementation of stricter safety standards. To address this imbalance, I proposed a multi-faceted strategy: fostering collaborative outreach programs between industry and communities, empowering labor unions and advocacy groups, and building a strong internal safety culture within plants. Together, these initiatives could help reduce the burden of risk on frontline communities while allowing the battery recycling industry to expand responsibly and support national climate goals.

The technical portion of my thesis involved a feasibility analysis of commercial-scale hydrometallurgical recycling of lithium-ion batteries. I evaluated the scalability of novel technologies to recycle 200,000 tonnes of SLIBs per year into battery-grade materials. As shown in the Block Flow Diagram (Figure 1), SLIBs are first shredded into a powder (black mass), then processed through a leaching stage using piranha solution—a highly corrosive mix of hydrogen peroxide and sulfuric acid—to extract metals into a liquid phase. The metals are then selectively precipitated into solid crystals by adjusting the solution's pH. This analysis identified several key areas for design improvement, with the potential to enhance both the profitability and economic viability of battery recycling at scale.

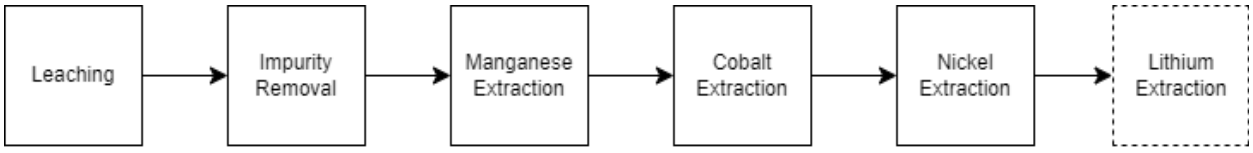

Figure 1: Hydrometallurgy Battery Recycling Block Flow Diagram (BFD)

Together, these projects demonstrate the importance of a sociotechnical approach to engineering. Technical solutions alone are insufficient if social and ethical risks are ignored. STS perspectives illuminate how engineering is always situated within broader networks of power, culture, and accountability. They challenge engineers not only to design safe and efficient systems, but also to take responsibility for the societal impacts of their work. This synthesis has deepened my commitment to engineering practices that are not only technically sound, but also socially just and ethically grounded.