PAHLE INDIA FOUNDATION
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Understanding the Used LEAD-ACID BATTERY RECYCLING ECOSYSTEM In India

TECHNICAL PARTNER
Vital Strategies

AUGUST 2024

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UNDERSTANDING THE USED
LEAD-ACID BATTERY (ULAB) RECYCLING ECOSYSTEM
IN INDIA

Author
Shreya Ganguly

ABBREVIATIONS

µg/dL - Micrograms per Deciliter

µg/m³ - Micrograms per cubic metre

mg/m³ - Milligrams per cubic metre

BLL- Blood Lead Level

BWMR - Battery Waste Management Rules

CAGR - Compound Annual Growth Rate

CMO - Chief Medical Officer

CSIR - Council of Scientific and Industrial Research

DPCC - Delhi Pollution Control Committee

DRS - Deposit-Refund Scheme

ELV - End-of-Life Vehicles

EPA - Environmental Protection Agency

EPR - Extended Producer Responsibility

ETP - Effluent Treatment Plant

EU - European Union

EVs - Electric Vehicles

HSN - Harmonized System of Nomenclature

IBER - Instituto Brasileiro de Energia Reciclável

IEED - International Institute for Environment and Development

ITI - Industrial Training Institutes

KORA - Korea Resource Circulation Service Agency

LAB - Lead-acid Battery

OPD - Outpatient Department

OSHA - Occupational Safety and Health Administration

Pb - Lead

PCCs - Pollution Control Centres

PEL - Permissible Exposure Limit

PNRS - National Solid Waste Policy

PPE - Personal Protective Equipment

RCRA - Resource Conservation and Recovery Act

SLI - Starting, Lighting and Ignition

SPCBs - State Pollution Control Boards

SRI - Sustainable Recycling Industries

SWM - Solid Waste Management

TCCA - Toxic Chemicals Control Act

TSIP - Toxic Sites Identification Program

ULAB - Used Lead-acid Batteries

UPS - Uninterrupted Power Supply

UPS - Uninterruptible Power Supply

VBWF - Volume-Based Waste Disposal Fee

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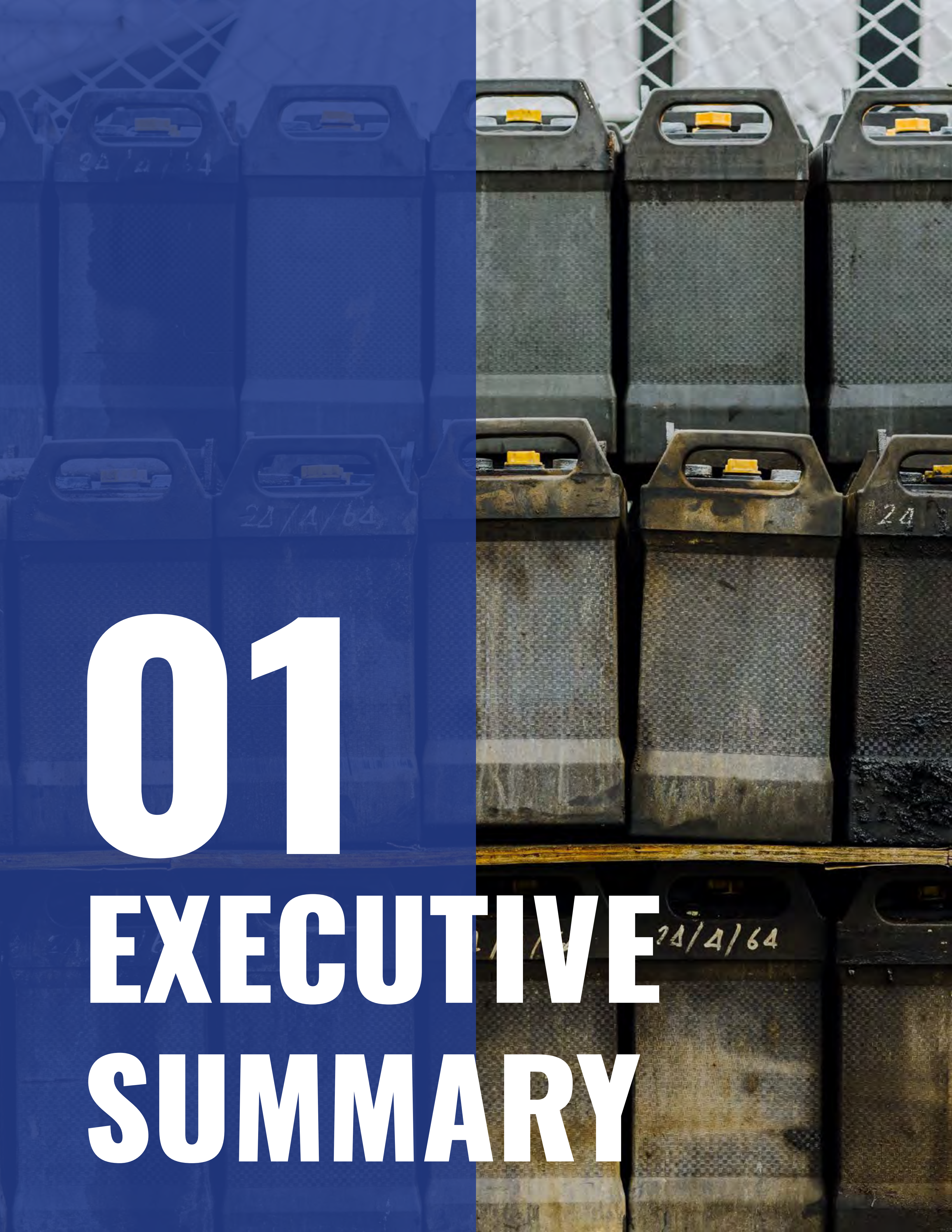
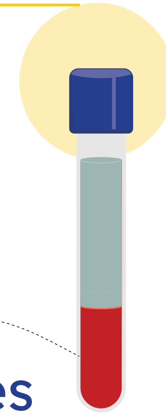


01 EXECUTIVE SUMMARY

Many facets of Indian industrialisation, and even the ongoing climate transition, depend heavily on **lead-acid batteries,** used in automobiles, UPS systems, energy storage in renewables systems like off-grid solar activity, etc. Of the **1.2 million tons** of used lead-acid batteries (ULABs) that enter India's recycling industry each year, **up to 90% are recycled informally**, as per estimates.[1] As the consumption of ULABs increases, their end-of-life management poses a **significant and rising environmental and health challenge.**



A systematic evaluation in India reveals that **blood lead levels (BLLs) among battery factory workers are over**

10 times higher

than those of healthy, age-matched controls.[2] A NITI Aayog-CSIR report from 2022 notes that **children living near lead-acid battery recycling units exhibit dangerously elevated BLLs, as high as 190 µG/dL. There is no safe level of lead in blood.**

The Batteries Waste Management (Amendment) (BWMR), Rules 2022 mandate a formal battery collection system, authorising only specific agents to collect used batteries for recycling. However, on-ground **implementation is reportedly delayed.** Informal recycling continues to dominate the ecosystem due to **lower costs and a more extensive collection network.**

[1] Loaded Leaded Batteries Mapping The Toxic Waste Trail. 2019. Toxics Link. Link

[2] Rao, G. M., Shetty, B. V., & Sudha, K. (2007). Evaluation of lead toxicity and antioxidants in battery workers. Biomedical research, 19(1), 1-4. Link

Within this context, this study aims to **deep dive into the on-ground functioning and dynamics of the ULAB ecosystem in India to identify concrete policy recommendations towards safe and environmentally-sound ULAB recycling.** To this end, the methodology employed is a combination of literature review, semi-structured interviews, and field observations.

Interviews with 11 ULAB recycling workers (three in the formal sector and 8 in the informal sector) in and around Patna, Bihar highlighted the highly dangerous and covert nature of the occupation, wherein informal operations are often conducted in residential and mixed use areas, with poor ventilation, insufficient pollution control technology, little to no protective gear, improper waste management practices, and immensely high risk of lead exposure to workers and the members of their household, including pregnant women and children. The interactions also underscored the lack of regulatory compliance in formal ULAB recycling units, which operate under regulatory oversight but still exhibit worrying lapses in safety protocol.

The primary research also revealed that **workers continue to stay within the informal ULAB recycling occupation for many years on end, given the high economic rewards.** Due to the **widespread lack of awareness around lead poisoning,** most are unaware that the health challenges faced by them and their family could point to lead poisoning.

Interviews conducted with three doctors and three hospital administrators in ULAB recycling hotspots of Patna, Bihar shed light on the lack of awareness around lead poisoning and dearth of medical capacity for blood lead level monitoring. It is alarming that there is **little to no medical capacity for the appropriate diagnosis and treatment of lead poisoning** near ULAB recycling hotspots.

Key policy recommendations to mitigate this pressing issue include

Reducing taxes on used batteries to improve the cost-competitiveness of the formal sector; mandating a **reverse logistics system** to promote the collection of used batteries; institutionalising **occupational guidelines and biological indices** defining an action level of lead in blood; entrusting **monitoring and evaluation to a third-party intermediary** between industry and government; **improving medical capacity for the diagnosis and treatment of lead poisoning** near ULAB recycling hotspots; encouraging the **mapping and remediation of contaminated sites;** conducting targeted **public health campaigns** among workers, health professionals and consumers; promoting **capacity-building of State Pollution Control Boards/Pollution Control Committees;** improving access to **alternative livelihoods;** and initiating **cluster development** for ULAB recycling units.

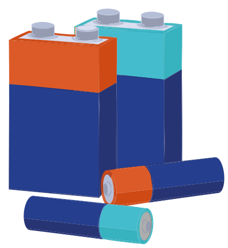
02 INTRODUCTION

As one of the oldest and most commonly-used battery technologies, the lead-acid battery (LAB) industry has been one of the largest consumers of lead in the world since its invention.

Indeed, lead-acid batteries account for

85%

of the world's demand for refined lead (Pb)[3].



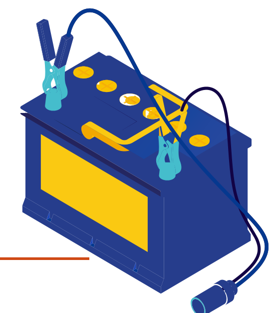
The lead-acid battery market in India was estimated at USD 4,495 million in 2023, and forecasted to grow at a CAGR of 6.80% between 2023 and 2029 to reach a market size of USD 6,566 million.[4]

Many facets of Indian industrialisation, and even the ongoing climate transition, depend heavily on lead-acid batteries. Lead-acid batteries are used in automobiles, trucks and other motorised vehicles for SLI (starting, lighting and ignition), as well as in power backup systems in telecommunications, railways, metro systems, hospitals, data centres, and industry, where uninterrupted power supply (UPS) is a necessity. They also play a crucial role in renewable energy systems. Solar panels and wind turbines use lead-acid batteries to store excess or unused energy to ensure a reliable supply of power. In smaller towns and remote rural areas, where grid connections are difficult, off-grid solar activity prevails and remains heavily reliant on lead-acid batteries. While lithium-ion batteries are the primary choice for EVs, lead-acid batteries continue to serve as auxiliary batteries in EVs. Moreover, lead-acid batteries are used in smaller electric vehicles, such as three-wheelers (e-rickshaws) and some four-wheel electric cars.

As the ULAB market grows, the end-of-life management of these batteries poses a significant and rising environmental and health challenge. A report from Toxics Link (a non-profit environmental NGO) from 2019 notes that around

90%

of the 1.2 Million tons of used lead-acid batteries



(ULABs) that enter India's recycling industry each year are recycled informally.[5] Particular concerns have been raised around ULABs discarded by the e-rickshaw segment, which already operates within the informal sector.

The informal recycling process is often carried out in densely populated areas, with little to no pollution control or safety precautions. The typical informal recycling process is as follows: the used battery cases are broken open using a machete or axe, the electrolyte (sulphuric acid) is dumped on the ground or into a sewer, the lead plates are removed by hand, and the separators are disposed of in a landfill. The lead plates are melted using a heat source, and the

3. Recycling used lead-acid batteries: brief information for the health sector. 2017. World Health Organization. Link
4. TechSci Research. Link
5. Loaded Leaded Batteries Mapping The Toxic Waste Trail. 2019. Toxics Link. Link

molten lead is then scooped out and poured into moulds to be sold to refiners and battery makers.[6] Open smelting of lead, open disposal of the battery electrolyte, and dumping of furnace residues are evident in many cities. It is estimated that approximately

6-7 lakh people

in India are employed within the ULAB recycling industry and depend on it for their livelihood.[7]

Informal recycling operations leach considerable amounts of lead into the surrounding ecosystem, including the air, soil, and water, which leads to environmental degradation and negative impacts on human health. Lead dust is released when batteries are broken and lead components are melted, rising into the air and seeping into the ground. Workers often touch lead components directly without gloves. Lead also ends up migrating to nearby communities on workers' clothes, in hair, on shoes, on vehicle tyres, through storm water run-off, wind, disposal of contaminated waste, etc.

A lead battery's main components, namely lead, plastic, and acid, are almost

100% recyclable,

and the lead can be recycled almost infinitely with no loss of performance.[8]

Well-regulated formal sector ULAB recycling contributes to sustainability and a circular economy, reducing the environmental and health impacts generated by the mining of lead. Moreover, recycling of ULABs is a necessity in India, as primary sources of lead are insufficient to satisfy the rising demand for lead. Hindustan Zinc Ltd. (LTD) is the country's only miner of lead, and produces about 211,000 tonnes annum of primary lead9, while lead consumption in India stands at about 838,000 tonnes.[10]

India is one of the largest ULAB importing countries, alongside Mexico, Canada, and Belgium, while the largest ULAB exporting countries are the US, France, the Netherlands, the UAE, and Germany.11 As such, a significant amount of lead is recovered through imports and recycling, much of which takes place in the informal sector.

6. Consequences of a Mobile Future: Creating an Environmentally Conscious Life Cycle for Lead-Acid Batteries. Global Battery Alliance. 2020. Link
7. Varshney, K., Varshney, P. K., Gautam, K., Tanwar, M., & Chaudhary, M. (2020). Current trends and future perspectives in the recycling of spent lead-acid batteries in India. Materials Today: Proceedings, 26, 592-602.
8. Battery Council International Website. Link
9. Hindustan Zinc Ltd. Website. Link
10. Statista. 2023. Link
11. International Lead and Zinc Study Group: An Analysis of Used Lead-acid Battery (ULAB) Trade and RelatedRegulations in North America. 2021. Link

03 RESEARCH DESIGN

Within this context, this study aims to deep dive into the on-ground functioning and dynamics of the ULAB ecosystem in India to identify concrete policy recommendations towards safe and environmentally-sound ULAB recycling.

To this end, the approach employed is as follows:

01 **Literature Review:** A detailed literature review was undertaken of existing academic papers, industry reports, laws, and regulations related to ULAB recycling. Successful formal recycling models and practices from other countries were identified and compiled.

02 **Stakeholder Consultation:** A roundtable discussion was held to gather inputs from key stakeholders, including formal battery manufacturers, formal recyclers, academics, scientists, doctors, think tanks, NGOs, policymakers from key regulatory bodies, etc.

03 **Semi-Structured Interviews:** Semi-structured interviews were held with the following groups:

- 11 ULAB recycling workers, to understand the unit economics and market dynamics of informal ULAB recycling, the safety and waste management protocol followed, and the health issues faced by workers and their community.
- Three doctors in hospitals located near ULAB recycling hotspots, to understand the level of awareness around lead poisoning in the medical system and the medical capacity to conduct blood lead level testing.
- Three hospital administrators in hospitals located near ULAB recycling hotspots, to learn about the procedure followed by hospitals for the disposal of inverters or UPS systems, which use ULABs.

04 **Field Observations:** Field visits were made to formal and informal recycling facilities, as well as hospitals near in ULAB recycling hotspots, to observe operations firsthand.

The primary research is focused geographically on Patna, Bihar for several reasons. According to the 2019 Toxic Sites Identification Program, Bihar has the highest number of ULAB recycling contaminated sites among all Indian states. Many reports indicate that Bihar is the state most severely impacted by lead poisoning. This case study of Bihar intends to develop practical policy recommendations that can be applied more broadly across India.

The sample size is limited due to the covert nature of informal ULAB recycling and the sensitivity of the issue. Conducting effective outreach requires a long-term, trust-based, and non-judgemental relationship. The survey was thus undertaken in partnership with a local NGO that works closely with informal ULAB recycling workers, namely the International Institute of Environment & Eco Development (IEED).

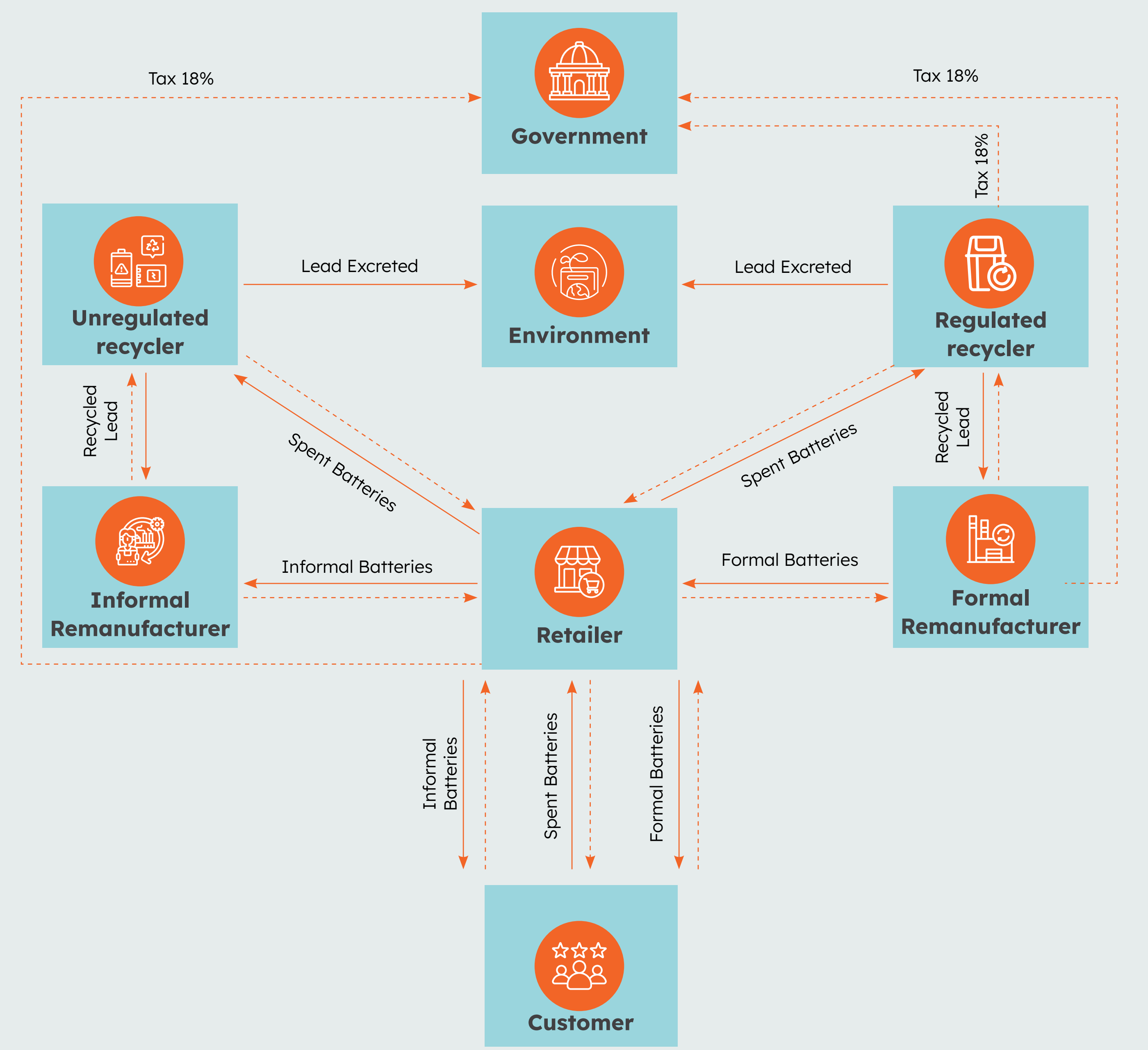
Given that the sample is small and non-representative, the data collected cannot be extrapolated to the population of ULAB recycling workers, doctors, or hospitals as a whole. However, valuable practical insights were gained through in-depth conversations with the respondents and general observations by the surveyors, given their proximity to and ongoing relationship with the stakeholders.

04 MARKET DYNAMICS

The ULAB recycling ecosystem can be mapped as follows. Customers purchase new batteries from retailers, choosing between branded/formal batteries and generic/informal batteries based on their respective prices and quality. They then sell the used battery to the retailers for a discount on the purchase of a new battery, because of the deposit-refund scheme (DRS) in place. They may also choose to sell the ULAB to a door-to-door garbage collector or kabadiwala, in return for a cash payment. Unsurprisingly, the prospect of an upfront payment in cash rather than a discount on a new battery, as well as the convenience of door-to-door collection, are highly appealing for consumers.

The retailers may be approached by two types of recyclers, formal and informal. Retailers choose to give it to a regulated or unregulated recycler based on the payment they receive for the used batteries. Unregulated recyclers typically offer higher prices and a higher purchase frequency, given the dense collection network of the informal sector, allowing the retailer to benefit from lower storage costs and tax elimination. Many retailers may thus prefer selling ULABs to the unregulated sector.

Both kinds of recyclers extract the lead and plastic from the batteries, with vastly different health and environmental consequences. Regulated recyclers supply lead to formal battery remanufacturers, while unregulated recyclers supply the lead to informal battery manufacturers. The lead extracted by unregulated recyclers is typically of lower purity and cheaper. The remanufacturers then rebuild the batteries and sell them to retailers.



Source: Joshi et al. (2021). Impact of policy instruments on lead-acid battery recycling. IIT Kanpur.

The following factors hinder the growth of the formal ULAB recycling industry:[12]

Cost-competitiveness: Informal recyclers do not use pollution prevention technology or comply with applicable environmental and occupational safety regulations, and thus face lower fixed and operating costs. An unauthorised backyard smelting facility requires no more than a stove and a container. Even if illegal recycling units

[12] Lead-acid Battery Recycling in India: Challenges and Next Steps. CEEW. Issue Brief. 2015. Link

are shut down, they can quickly resurface elsewhere. Formal recyclers must comply with environmental regulations and pay for infrastructure, land acquisition, building construction, maintenance, machinery running costs, etc. By saving on these expenses, informal sector units can afford to pay consumers and retailers more to collect used batteries from them than a formal recycler. Informal sector operators can also afford to sell refurbished or remanufactured batteries to consumers, and secondary lead ingots to industries, at a lower price than their formal sector counterparts. Stakeholders indicate that industries prefer to purchase secondary lead from unlicensed recycling units and backyard smelters because of their lower prices.

Moreover, the GST rate in India on the waste and scrap of primary cells, primary batteries, and electric accumulators is 18% under HSN Code 8506, which formal sector retailers, recyclers, and remanufacturers are required to pay. The informal sector operates outside of regulatory purview and thus does not pay this tax, which further hurts the economic viability of formal recycling.

Low collection frequency: The informal collection network of kabadiwalas (door-to-door garbage collectors) visits retailers and consumers more frequently than manufacturer representatives, and in turn, typically passes on the collected ULABs to informal smelters. The convenience of door-to-door collection in exchange for upfront payment is far more appealing for consumers and retailers than the prospect of dropping off used batteries at collection centres.

Low feedstock: Given ULAB diversion to informal recyclers, formal recyclers face underutilised plant capacity and less feedstock than necessary to maintain operations. They are forced to depend on alternate sources of feedstock, such as remelted lead imports or even remelted lead from informal players. Many stakeholders indicate that due the the lack of a robust collection process in the formal sector, formal recycling plants often operate below capacity.

Lack of data for policy interventions: Data required for sound and implementable policy amendments (e.g. proportion of market share of formal vs. informal recycling, processes used by informal smelters, price differentials between formal and informal systems, mapping of recycling hotspots, number of workers exposed etc.) remains scarce and out of date, given the difficulty of tracking informal sector activity.

These factors present significant and persistent bottlenecks to the formalisation of ULAB recycling, and help explain why the informal sector continues to dominate the ecosystem despite its negative environmental and health consequences.

05 HEALTH AND ENVIRONMENTAL IMPACTS

Informal recycling of used lead-acid batteries is extremely dangerous for human beings and the environment. A systematic evaluation conducted in India reveals that blood lead levels (BLLs) among battery factory workers are over 10 times higher than those of healthy, age-matched controls.[13] Various small-scale studies of battery workers in India report BLLs as high as

65.5 µg/dL[14].

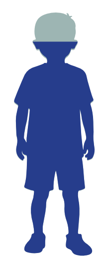
A review of studies from 37 developing countries finds that the average worker BLL is 47 µg/dL in battery manufacturing plants and 64 µg/dL in recycling facilities.15 For context, the **Occupational Safety and Health Administration (OSHA) guidelines** require medical removal of a worker if a BLL of 50-60 µg/dL is reached, permitting them to return to work only after 2 consecutive measurements below 40 µg/dL.[16] **The CPCB SOP** for ULAB Recycling notes that individuals with BLLs higher than 42 µg/dL should be shifted to non-lead activity areas until their BLL falls to below 10 µg/dL.[17]

Airborne lead concentration reported in battery plants in developing countries is 367 µg/m3 on average, which is 7-fold greater than the permissible exposure limit of 50 µg/m^3 (or 0.05 mg/m^3) advised in the CPCB SOP, as well as the OSHA guidelines.

The families of ULAB workers and those living near ULAB recycling sites are exposed through various channels. Lead in contaminated soil on playgrounds enters childrens' bodies through hand-to-mouth behaviour, the inhalation of lead-containing smoke, and lead dust is brought into the home through the parent's clothes, shoes, hands, and hair. A 2022 NITI Aayog-CSIR report finds that children living near lead-acid battery recycling centres exhibit dangerously elevated BLLs, as high as 190 µG/dL.

An assessment of prevalence of elevated blood lead levels and risk factors among children and pregnant women in eight districts of Bihar finds that more than

90% of children



and

80%

of pregnant women

reported blood lead levels above 5 µg/dL, and that living near a lead-related industry and

[13] Rao, G. M., Shetty, B. V., & Sudha, K. (2007). Evaluation of lead toxicity and antioxidants in battery workers. Biomedical research, 19(1), 1-4. Link

[14] Himani, Kumar, R., Ansari, J. A., Mahdi, A. A., Sharma, D., Karunanand, B., & Datta, S. K. (2020). Blood lead levels in occupationally exposed workers involved in battery factories of Delhi-NCR region: effect on vitamin D and calcium metabolism. Indian Journal of Clinical Biochemistry, 35, 80-87. Link

[15] Gottesfeld, P., & Pokhrel, A. K. (2011). Lead exposure in battery manufacturing and recycling in developing countries and among children in nearby communities. Journal of occupational and environmental hygiene, 8(9), 520-532. Link

[16] Lead in the Workplace: Blood Lead Level Guidance. Centers for Disease Control and Prevention (CDC). Accessed 23 July 2024. Link

[17] Standard Operating Procedure for Recycling of Lead Scrap/Used Lead-acid Batteries, 2024, CPCB, https://cpcb.nic.in/openpdffile.php?id=TGF0ZXN0RmlsZS80MDZfMTcwNTU4MDIxNV9tZWRpYXBob3RvMjYyNTcucGRm

[18] Ibid.

[19] Kumar, Rakesh et al. (2022). Assessment of Lead Impact on Human and India's Response. NITI Aayog and Council of Scientific and Industrial Research (CSIR). Link

pica behaviour of eating soil were associated with elevated blood lead levels.[20] Ansari et al. (2020) find that among 41 children residing near informal LAB manufacturing units, 91% children had a BLL above 5 µg/dL.[21]

In developing countries, BLLs among children who live near or work in ULAB recycling sites have been found to be about five times higher than those in unexposed children.[22] In another study, the average BLL of children residing near battery plants in developing countries was 19 µg/dL, about 13-fold greater than the levels observed among children in the United States.[23]

An assessment by Pure Earth reveals that lead levels in the soil around informal recycling hotspots exceed **60,000 parts per million,** about 150 times higher than international health standards for soil in play areas.[24] Brown et al. (2020) find that lead concentrations in environmental samples were significantly higher in households located in proximity to ULAB recycling operations, compared to those located further away.[25] Moreover, several cases of cattle deaths in Delhi were attributed to lead poisoning from nearby unlicensed lead smelting units.[26]

Children are particularly vulnerable because they absorb 4-5 times as much lead as adults from a given source, and can suffer from reduced intelligence, lower educational attainment, and more delinquent and violent behaviour as a result of lead poisoning.[27] For children and adults alike, cumulative lead toxicity over time can attack the brain and nervous system and cause damage to multiple organs. Lead poisoning can cause adults to suffer from cardiovascular problems, immunotoxicity, and kidney damage.[28] In pregnant women, high lead exposure can cause miscarriage, stillbirth, premature birth, and low birth weight.29 Larsen (2023) estimated that children younger than five years lost 765 million IQ points and that 55,45,000 adults died from cardiovascular disease in 2019 due to lead exposure, concluding that global lead exposure has health and economic costs **at par with particulate matter air pollution.[30]**

ULAB recycling, thus, is dangerous not only for the workers who engage in the actual recycling processes but poses a risk to the entire family, who often live above or near the smelting area and engage with the worker, who brings home lead on his clothes and body. Children and pregnant women in the household are especially vulnerable to lead poisoning, and may suffer from high blood lead levels even if they do not directly work on the batteries. Moreover, as lead leaches into the surrounding ecosystem, the local communities also face the negative externalities of informal ULAB recycling operations.

20. Lu, Y., Chandan, A. K., Mehta, S., Kushwaha, M., Kumar, A., Ali, M., and Kass, D. (2024). Assessment of prevalence of elevated blood lead levels and risk factors among children and pregnant women in Bihar, India. Environmental Research, 259, 119528. Link
21. Ansari, J. A., Mahdi, A. A., Malik, P. S., & Jafar, T. (2020). Blood lead levels in children living near an informal lead battery recycling workshop in Patna, Bihar. Journal of Health and Pollution, 10(25), 200308. Link
22. Hirst, R. et al. (2023). How to Stop Automotive Battery Recycling from Poisoning Our Children. Asian Development Bank (ADB) Brief No. 267. Link
23. Gottesfeld, P., & Pokhrel, A. K. (2011). Review: Lead exposure in battery manufacturing and recycling in developing countries and among children in nearby communities. Journal of occupational and environmental hygiene, 8(9), 520–532. Link
24. Pure Earth. Link
25. Brown, M. J., Patel, P., Nash, E., Dikid, T., Blanton, C., Forsyth, J. E., ... & Shrivastava, A. (2022). Prevalence of elevated blood lead levels and risk factors among children living in Patna, Bihar, India 2020. PLOS Global Public Health, 2(10), e0000743. Link
26. Prajapati, S. (2016). Lead-acid battery recycling in India. IOSR J. Electr. Electron. Eng, 11, 2278-1676.
27. Kumar, Rakesh et al. (2022). Assessment of Lead Impact on Human and India's Response. NITI Aayog and Council of Scientific and Industrial Research (CSIR). Link
28. World Health Organisation. Link
29. Ibid.
30. Larsen, B., & Sánchez-Triana, E. (2023). Global health burden and cost of lead exposure in children and adults: a health impact and economic modelling analysis. The Lancet Planetary Health, 7(10), e831-e840. Link

06

REGULATORY FRAMEWORK IN INDIA

India is a signatory to the international treaty of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal - Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries, 1989. The Basel Convention was introduced with the overarching aim of protecting human health and the environment against the adverse effects of hazardous wastes. The Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries, under the Basel Convention, provide a framework for handling these batteries responsibly. They outline procedures for the collection, transportation, storage, and recycling of ULABs to minimise environmental impact and promote sustainable practices.

Owing to India's welfare duties and international obligations, a legal framework aligned with the Basel Convention has evolved over time. The following regulatory framework currently stands in India:

Hazardous Waste Management Rules, 2016

The Hazardous Waste Management Rules, 2016[31], provide a comprehensive framework for the management of hazardous waste. These rules define hazardous waste and detail the responsibilities of hazardous waste generators, transporters, and operators of disposal facilities. The rules mandate obtaining authorization for handling hazardous waste, maintaining records, and submitting annual returns to the State Pollution Control Boards. Additionally, they emphasise waste minimisation, recycling, and safe disposal methods, citing lead as a hazardous substance.

Protocol for Evaluation of Technology for Waste Management, 2021

Despite the availability of several global technologies for waste processing, agencies responsible for implementing waste management projects often face challenges with technology providers promoting their solutions. In many cases, this technology is imported. Some of these technologies fail to deliver the expected results due to a lack of adaptation to local conditions. There is a need to standardise these technologies to suit the Indian scenario. These rules[32] standardise such technologies by considering capital and operational costs, technological complexity, environmental impact, feasibility under local conditions, etc.

[31] Hazardous and other Waste Management Rules, 2016, CPCB. (n.d.). https://cpcb.nic.in/displaypdf.php?id=aHdtZC9IV01fUnVsZXNfMjAxNi5wZGY.
[32] Protocol for Evaluation of Technology for Waste Management, CPCB, https://cpcb.nic.in/uploads/Technology_WM_1.pdf

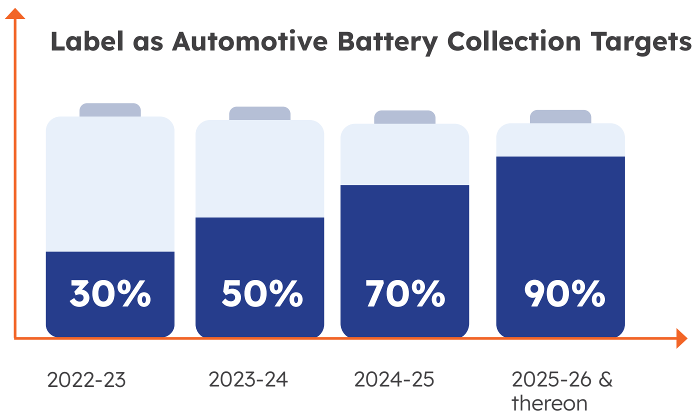
Batteries Waste Management Rules, 2022

Before these rules[33] came into being, the Batteries Waste Management & Handling Rules, 2001 governed waste management for batteries. The 2022 amendment has introduced a separate provision on **Extended Producers Responsibility (EPR).** requiring manufacturers to ensure that the batteries they introduce into the market are either recycled or refurbished. Producers must incorporate a minimum amount of domestically-recycled materials into new battery production. Moreover, consumers and public waste management authorities are tasked with responsibly discarding waste batteries separately from other waste streams and ensuring they are handed over to entities engaged in collection, refurbishment, or recycling. Recyclers and refurbishers must register with State Pollution Control Boards and issue certificates for waste battery processing, which can be used to meet EPR obligations. The Central Pollution Control Board oversees the issuance of Extended Producer Responsibility certificates based on recycled or refurbished quantities. Based on the

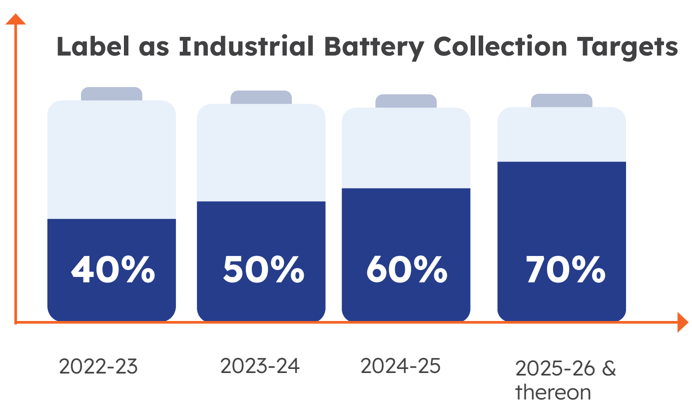
polluter pays principle,

the producers shall be liable to pay compensation in case of violations, such as operating without registration, providing false information, or mishandling waste batteries. However, payment of environmental compensation does not absolve producers of their extended producer responsibility obligations.

Targets are outlined for the collection of the batteries placed in the market by the producer, following which 100% of the batteries collected must be refurbished or recycled within seven years. For automotive batteries, the targets for collection are 30% by 2022-23, then 50% by 2023-24, then 70% by 2024-25, and 90% by 2025-26 and thereon.



For industrial batteries, the targets are 40% by 2022-23, then 50% by 2023-24, then 60% by 2024-25, and 70% by 2025-26 and thereon.[34]



Non-fulfilment of obligations under the Rules carries a penalty of imprisonment up to 5 years, or a fine up to Rs. 1,00,000, or both.

33. Batteries Waste Management Rules, 2022, CPCB, https://cpcb.nic.in/uploads/hwmd/Battery-WasteManagementRules-2022.pdf. Accessed 26 Apr. 2024.
34. Lead-acid batteries fall under the categories of 'automotive batteries' and 'industrial batteries', as classified in the Battery Waste Management Rules, 2022.

Standard Operating Procedure for Recycling of Lead Scrap/Used Lead-acid Batteries, 2024

These rules[35] describe, in detail, guidelines around everything from the collection of the batteries to the final disposal of their components. The SOP is designed to regulate the import, transport, and recycling of lead-bearing waste, while minimising environmental and health risks. The SOP suggests standards for lead emissions, including limits for lead in the work area. It also recommends the annual monitoring of workers' blood lead levels, suggesting that individuals with BLLs higher than the acceptable limit (42 µg/dL) should be relocated to non-lead activity areas and provided specialised medical treatment until their BLLs return to an acceptable range (10 µg/dL). However, it is left up to the discretion of State Pollution Control Boards (SPCBs)/ Pollution Control Centres (PCCs) to prescribe these standards in their jurisdiction.

The SOP outlines the minimum required facilities for a ULAB recycling unit to be deemed safe and environmentally-sound, including a rotary furnace or mandir bhatti connected with an expansion chamber, cooling tubes or ducts, a suction hood for manual dismantling of batteries connected to a pollution control device, an Effluent Treatment Plant (ETP) plant to treat waste water and neutralise acid, an automatic battery-breaking unit if the operation has over 5000 MTA capacity, an arrangement for noise control in case an automatic battery-breaking unit is present, adequate facilities for safe collection and storage, facilities for the washing of plastic components and tyres of trucks transporting batteries, etc.

The SOP also emphasises the accountability of the occupier, whether sender or receiver, for any environmental damages resulting from improper handling of battery wastes, including accidental spillage throughout the entire lifecycle. It requires those handling hazardous wastes to promptly address and rectify any environmental harm they may cause, thus contributing to a comprehensive and responsible approach to waste management.

The above laws regulate the recycling, treatment and disposal of Used Lead-acid Batteries (ULABs). While major formal battery manufacturers like Amaraja and Exide comply with these guidelines as per their Annual Reports[36], the formal sector by many accounts comprises no more than a small percentage of the total ULAB recycling ecosystem. A substantial portion of ULABs is recycled by the informal sector, who operate outside the scope of regulations, and typically disregard established environmental standards and regulations. Informal recyclers have no incentive to comply with the Rules, given that they are not registered with the CPCB or any other regulatory authority. This makes workers in the informal recycling sector highly vulnerable to occupational hazards like lead exposure. In addition, the disposal practices followed in this sector are frequently far from environmentally-friendly, leading to the contamination of the surrounding air, water and soil.

35. Standard Operating Procedure for Recycling of Lead Scrap/Used Lead-acid Batteries, 2024, CPCB, https://cpcb.nic.in/openpdffile.php?id=TGF0ZXN0RmlsZS80MDZfMTcwNTU4MDIxNV9tZWRpYXBob3RvMjYyNTcucGRm0
36. Exide Annual Report 2023-24. Link Amararaja Annual Report 2023-24. Link

Monitoring and enforcement of the regulatory framework reportedly lags behind, given that informal recycling operations are commonplace.[37] Over 200 lead-contaminated sites associated with battery recycling and repair activities have been flagged in Bihar and Jharkhand.

Of these sites, 90% have recorded soil lead concentrations surpassing the standards set by the US Environmental Protection Agency.[38]

The Delhi Pollution Control Committee

(DPCC) has, in the past, shut down approximately 46 illegal units due to their classification as highly polluting and hazardous.39 However, these figures are likely a massive underestimate, since mapping non-compliant ULAB recycling units is challenging, given the difficulty of tracking informal sector operations.

The national dashboard of **CPCB EPR Portal for Battery Waste Management** presents data on the status quo of the implementation of the Battery Waste Management Rules, 2022. The tables below depicts key figures as on August 23, 2024:

Lead EPR Targets for Registered Producers (in Tonnes)

2022-23	2022-23	2024-25
2,03,563	3,14,159	4,66,079

Source: CPCB National Dashboard, Link

The EPR targets for lead for registered producers have been steadily increasing each year.

Availability Status of EPR Credits

EPR Target (in tonnes) FY 24-25	EPR Credits Generated by Recyclers	EPR Credits Available	EPR Credits Transferred to Producers
4,66,079	12,560	3,30,309	1,37,707

Source: CPCB National Dashboard, Link

37. Ibid.
38. Pahle India Foundation - Awareness Campaign and Promotion of Social and Behavioural Change on Lead Poisoning in Bihar and Jharkhand
39. Prajapati, S. (2016). Lead-acid battery recycling in India. IOSR J. Electr. Electron. Eng, 11, 2278-1676.

The EPR Target for FY 2022-23 is 466,079 tonnes, while the EPR credits generated are 12,560 tonnes. The generated credits are significantly lower than the target. This indicates a discrepancy between the statistical data and the actual ground reality, highlighting a collection gap between the formal and informal sectors. To bridge this gap, it is crucial to raise awareness among all stakeholders. Although the government is making efforts in this area, more needs to be done.

Application Status of Battery Registration in FY 2023-24

Category	Total Number Received	In-Process	In-Complete	Registration Issued
Producer	3,422	220	517	2685
Recycler	521	158	123	240

Source: CPCB National Dashboard, Link

As of FY 2023-24, 521 applications have been made to register with the CPCB as a battery recycler (for all kinds of batteries and not only ULABs), out of which 158 are in process, 123 are incomplete, and 240 registrations have been issued.

07 PRIMARY RESEARCH FINDINGS

Survey Area: Bihar, India

The state of Bihar, India was selected as a case study for primary research. Based on the Toxic Sites Identification Program in 2019, Bihar in the northeast of India is home to the largest number of ULAB recycling contaminated sites of all states in India. By many accounts, Bihar is the state worst affected by lead poisoning. According to a report from CSIR and NITI Aayog (2022), the average BLL in Bihar is

10.42 µg/dL,

well over twice the WHO threshold for intervention of 5 µg/dL.[40]

Data from 2019 indicates that 18,830,782 Bihari children aged 0-14 have BLLs above 5 µg/dL, and 4,162,335 have BLLs above 10 µg/dL.[41] Moreover, a 2024 assessment finds that 90% of children tested in eight districts of Bihar had BLLs above 5 µg/dL.[42]

The Pure Earth Toxic Sites Identification Program (TSIP) (2019) identifies 36 sites contaminated by battery recycling in Bihar, with a population at risk of approximately 101,587.[43]

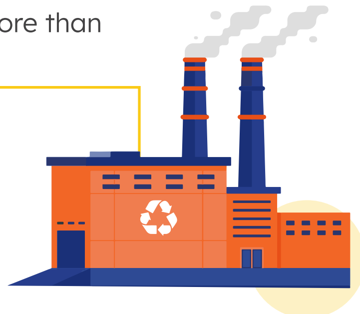
Additionally, Bihar ranks among the states with the lowest GDP per capita, contributing to no more than 3.1% of the country's total GDP.[44] Bihar's urbanisation rate stood at a mere 11% compared to the national rate of 31%, as per the 2011 census.[45] The state also has the lowest composite score in terms of progress towards the UN Sustainable Development Goals.[46] These factors, combined with its large population of 104 million (third largest in the country), present a major challenge for the enforcement of safety and environmental regulations, but also a significant opportunity for lead poisoning mitigation efforts to maximise impact.[47]

Given that Bihar is bordered by Nepal and Bangladesh, cross-country flows of battery scrap reportedly take place on a regular basis. A significant number of ULABs from Nepal and Bangladesh come to Bihar for recycling in the informal sector. As the EPR targets for battery collection are set on a national level, stakeholders indicate that the majority of battery collection by formal manufacturers occurs in well-connected urban centres like Mumbai and Delhi, with many lead-acid batteries in remote and rural areas left to reach the informal sector instead.

40. Kumar, Rakesh et al. (2022). Assessment of Lead Impact on Human and India's Response. NITI Aayog and Council of Scientific and Industrial Research (CSIR). Link
41. Ibid.
42. Lu, Y., Chandan, A. K., Mehta, S., Kushwaha, M., Kumar, A., Ali, M., and Kass, D. (2024). Assessment of prevalence of elevated blood lead levels and risk factors among children and pregnant women in Bihar, India. Environmental Research, 259, 119528. Link
43. Pure Earth Toxic Sites Identification Program. Link
44. RBI Handbook of Statistics on Indian States. Link
45. Jha, R. (2022). Speeding Up Bihar's Urbanisation. ORF Expert Speak. Link
46. PIB Press Release. Link
47. RBI Handbook of Statistics on Indian States. Link

In total, there are no more than

4 formal ULAB recycling units



in Bihar registered under the Bihar State Pollution Control Board as of March 2021, with a total authorised capacity of 6870 MTA.[48] They are located in industrial areas in the districts of Patna, Muzaffarpur, and Rohtas.

Interviews with Used Lead-acid Battery Recycling Workers

Semi-structured interviews were held with

11 Workers

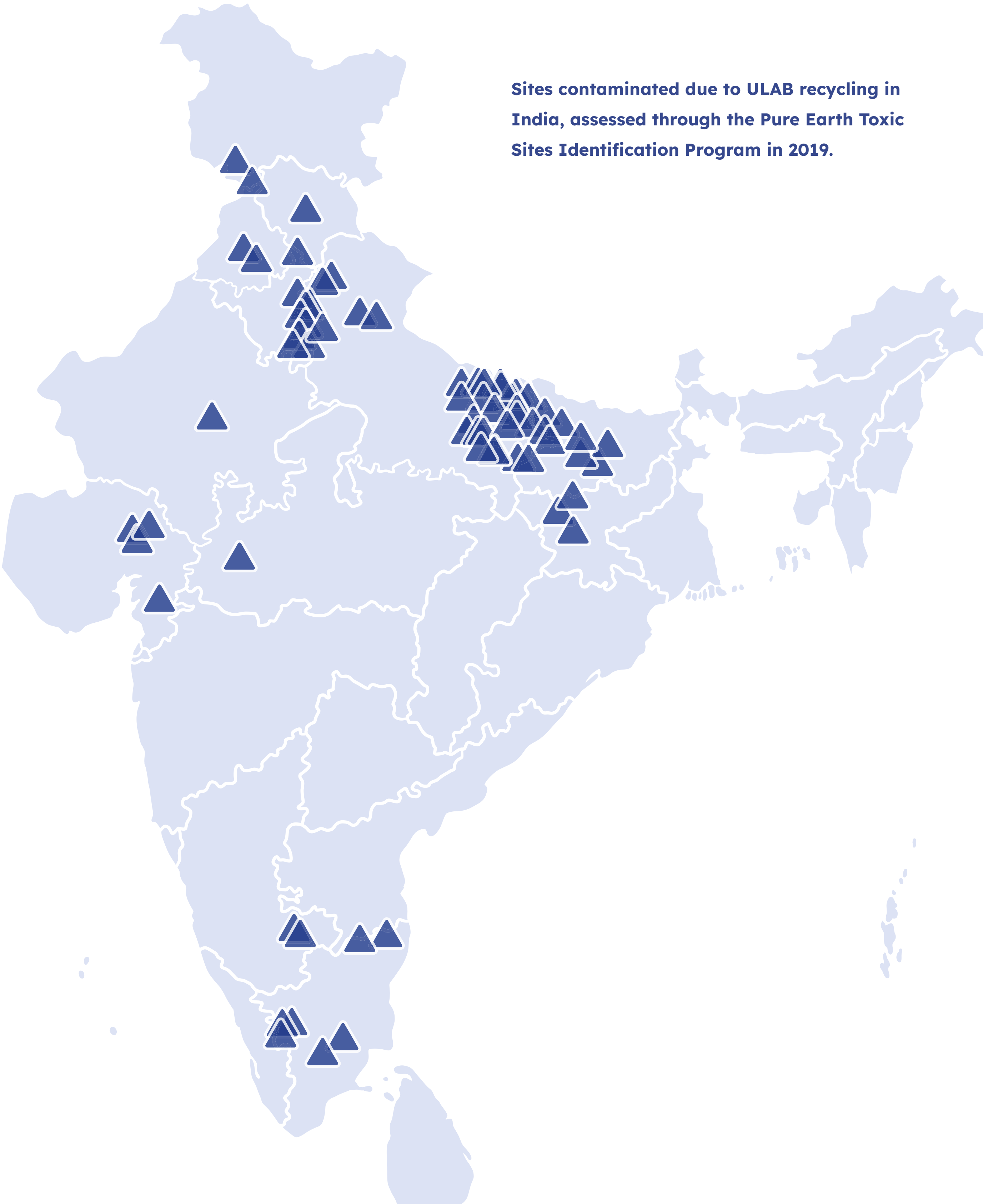
from different units in ULAB recycling hotspot areas of Bihar to gain an insight into the on-ground operations of the ULAB recycling ecosystem.

Given that informal ULAB recyclers work covertly, conducting effective outreach requires a long-term, trust-based, and non-judgemental relationship. The survey was thus conducted in partnership with a local NGO that works closely with informal ULAB recycling workers, namely the **Institute of Environment & Eco Development (IEED).** The thematic areas covered in the interview included the unit economics and market dynamics of ULAB recycling, the safety and waste management protocol followed, the health issues faced by workers and their community, etc.

Snowball sampling was used to identify and approach respondents; ULAB recycling workers known to the surveyor were asked to help reach out to others in the area. Multiple visits were made to each respondent to build trust and gain truthful insights, due to their hesitancy in revealing sensitive information, given the illegality of their operations. The confidentiality of participants' identities has been maintained, and all participants provided informed consent before taking part in the study. Questionnaires were prepared on the basis of extensive literature review, and underwent multiple iterations through consultations with experts.

Given that the sample is small and non-representative, the data collected cannot be extrapolated to the population of ULAB recycling workers as a whole. However, valuable practical insights were gained through in-depth conversations with the workers and general observations by the surveyors, given their proximity to and ongoing relationship with the informal ULAB recycling community.

[48] Central Pollution Control Board, March 2021. Link



Sites contaminated due to ULAB recycling in India, assessed through the Pure Earth Toxic Sites Identification Program in 2019.

Sample Profile

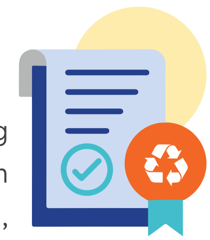
- 11 workers from ULAB recycling units located in and around Patna and Muzaffarpur were identified and approached for the survey.
- All the workers surveyed were male, from the ages of 27 to 53, with an average age of 42 across the sample.
- The respondents stated that the typical profile of workers in ULAB recycling units was men in the age range of 18-45, with the exception of one respondent (a formal recycler), who reported both male and female employees working in the unit.
- Six of the respondents owned their recycling unit, while the rest were workers.
- The units performed some or all activities in the battery recycling value chain, including dismantling and separating battery components, smelting lead, refining lead, and making batteries.
- The respondents had all been working in ULAB recycling for a significant period of time, with their experience in the industry ranging from 2 years to 20 years, with an average of 11 years of experience.
- About 70% of the respondents had migrated to Patna for work from other districts of Bihar or other states, such as Punjab or Rajasthan.
- Many had shifted back to Bihar after the COVID-19 pandemic in search of employment opportunities.

Informal vs. Formal Recycling Units

Only

three

of the respondents reported having a formal ULAB recycling licence from the Central Pollution Control Board, while eight were unregistered units.



The three formal sector units stated that they filed regular reports and returns with the CPCB, and received monthly visits from the State Pollution Control Board.

For the purposes of the survey, smelting operations were classified into three categories in order of industrial advancement and the soundness of safety and waste management protocol followed:[49]

01 **Backyard smelting:** Smelting in backyard or kitchen, manual separation of battery components through hammers, no protective gear, waste thrown in soil or drains, highly polluting, and extremely unsafe.

02 **Low standard industrial smelting:** Smelting in chambers or pits / bhattis (open or closed), manual separation through hammers, little to no protective gear, waste thrown in soil or drains, highly polluting, and unsafe.

03 **High standard industrial smelting:** Smelters with air handling systems to filter toxic lead dust, carried out in a factory environment, separator machines to dismantle battery components, proper waste management, protective gear used, environmentally-safe with multiple provisions in place to safeguard human health.

[49] The classification has been adopted from a report on 'Standard Operating Procedures for Environmentally Sound Management of Used Lead-acid Batteries' by Sustainable Recycling Industries (SRI) in December 2021. Link

Each recycling unit was classified based on field observation, according to these criteria. Among the three formal sector operators, two were identified as low standard industrial smelters and one was identified as a high standard industrial smelter. The backyard smelters were typically one-person operations. The formal units were larger operations, with the largest formal sector unit surveyed having around 25 employees. The formal units were located in industrial areas.

All the eight informal sector operators were identified as backyard smelters. Most were located in residential and mixed use areas. The surveyor reported that many conducted ULAB recycling activity within their residence, often with smelting work carried out on the ground floor and their living quarters upstairs. To avoid detection from local authorities, many conducted smelting activity indoors, leading to even poorer ventilation. Households conducting informal ULAB recycling activities were typically surrounded by visible fumes. The surveyors also came across a ULAB recycling unit located below a school.

An informal ULAB recycling unit operating below school premises (Source: IEED, 2024)

Many small-scale retailers of batteries secretly conducted informal ULAB smelting operations a few kilometres behind their store, and sold these informally-produced batteries alongside branded, formal sector ones, particularly in the residential Kankarbagh area of Patna.

Battery retailers in a residential area of Patna (Source: IEED, 2024)

Storefronts of small-scale battery retailers in Patna (Source: IEED, 2024)

One of the formal units originally began as an informal operation and was formalised only later. After about two decades of experience in informal recycling, the owner decided to apply for CPCB registration, upgraded the recycling unit technologically, and subsequently received a licence. Additionally, one of the formal units had its licence revoked after an SPCB visit due to a safety protocol violation involving the presence of pregnant and lactating women in the unit. Once safety protocol was properly followed, the licence was reinstated.

Children playing behind an informal ULAB recycling site (Source: IEED, 2024)

Unit Economics and Market Dynamics

Most of the units worked with wet cell batteries (flooded lead-acid batteries with liquid electrolyte) or dry cell batteries (sealed or maintenance-free batteries without liquid electrolyte) only. One formal unit recycled a variety of raw materials like wet cell batteries, dry cell batteries, lead dust, lead bricks, and other lead-containing waste from industries. The raw materials (battery scrap) were received from various sources, mainly kabadiwalas (door-to-door scrap collectors), battery dealers and manufacturers themselves, battery collection centres, industries, etc. The informal sector operators sold finished batteries and lead ingots, while formal sector operators only sold lead ingots. **Notably, many informal sector respondents indicated that the lead ingots they produced were purchased by formal sector battery manufacturers (particularly medium and small ones), who collected them in trucks.**

The battery scrap was purchased by the recyclers for around

INR 120 per kilogram

ranging from a price of INR 90 to INR 300 per kilogram, with no significant difference in price paid between the informal and formal sector. The price at which the scrap was bought depended on the individual recycler's bargaining power.

The formal sector units typically worked at a larger scale, with higher amounts of ULABs received daily for recycling, between 30 and 50 MT a day. The informal backyard units typically only received around 2-3 MT a day. Small backyard units typically manufacture 4-6 batteries and repair 2-3 batteries daily. **The formal sector respondents reported that the cost of running the recycling unit each month ranged from INR 2 lakh to 5 lakh, while informal sector respondents did not track or report any cost figures.**

The informal sector sold recycled batteries at a lower price than formal sector manufacturers. Indeed, the surveyors believed that the batteries produced by the informal sector had a higher shelf life than formal sector ones. The informal battery manufacturers state that they have zero costs in terms of pollution control technology, marketing, etc., and as such are able to fully invest their resources into producing batteries that last longer.

The average reported monthly income of all the respondents was INR 1.4 lakhs, with incomes ranging from INR 20,000 a month to INR 4 lakhs

a month. Informal sector operators, on average, earned a higher income than formal sector ones. The surveyors, based on their field experience, believed that the incomes of the informal sector were significantly underreported, suggesting that an individual's earnings from running a small-scale unit were closer to INR 2-3 lakhs a month, and the total income of a large-scale informal recycling unit could be as high as INR 10-12 lakhs per month.

Almost all respondents stated that they had not considered taking up any other occupations. Over their many years of experience, they had developed significant technical expertise in ULAB recycling and earned a high income each month, compared to other occupations accessible to them in the informal sector. As a result, they had no incentive to explore alternative livelihoods.

The surveyors note that the informal ULAB recycling sector is dominated by the OBC and SC community and also largely has received low levels of schooling.

Informal recycling of ULABs taking place in open air (Source: IEED, 2024)

Safety and Waste Management Protocol

All of the respondents poured the battery acid into water outlet chambers, which went into the sewage system, without any treatment. Notably, this included the formal sector operators. The CPCB Standard Operating Procedure for ULAB recycling requires an Effluent Treatment Plant (ETP) with a provision for acid neutralisation. Even the recyclers with valid CPCB licences did not comply with this requirement.

All respondents dismantled batteries manually. The plastic container of the battery was typically reused by the unit. All respondents stated that the other components of the battery were sold to the kabadiwala, to be given to other local recyclers. Sodium sulphate crystals from the used electrolyte can be recycled and sold for use in textiles, glass, and detergent manufacturing - however, this economic opportunity remained entirely untapped.[50]

8/11
of the workers changed clothing after shifts.

8/11
of the workers ate meals in a separate area to the unit's premises, two ate it within premises, and two declined to respond. Six respondents stated that members of their household, such as their wife and children, frequently visited the recycling unit. For many, exposing their family members to the unit was unavoidable, as they conducted smelting activities within their residence.

[50] Consequences of a Mobile Future: Creating an Environmentally Conscious Life Cycle for Lead-Acid Batteries. Global Battery Alliance. 2020. Link

The CPCB Standard Operating Procedure for ULAB recycling requires workers to be equipped with Personal Protective Equipment, including a PPE kit, eyeglasses, mask, rubber gloves, shoes, and a readily available emergency kit. All the three formal sector units reported using gloves, special footwear like rubber boots, breathing masks, and protective clothing on top of daily wear. Four of the informal sector respondents used no protective wear, while others used only some of the required protective wear.

All respondents stated that they had considered adopting more protective wear and technology towards safe and environmentally-sound recycling, and that they were willing to invest in more equipment and technology. **None of them had other jobs, indicating that ULAB recycling was their only source of livelihood. All except one performed ULAB recycling year round, while the one respondent took seasonal breaks and noticed health improvements during his breaks.**

All respondents were well-aware of the illegality of their operations. While many in the community had paid fines before, none had previously gone to jail as they would typically abscond at short notice when found out by local authorities. Since many informal operations take place indoors within residential areas with low police presence, regulatory oversight and enforcement are difficult. Many operate at night to avoid detection. Moreover, bribing local authorities and middlemen to avoid apprehension was a common practice.

A worker performing informal ULAB recycling without any protective wear (Source: IEED)

Health Concerns

It must be noted that health symptoms related to lead poisoning are not obvious or specific, and thus are often ignored. Despite affecting children's health even at very low levels of exposure, the symptoms may not be obvious until a moderate or high level of exposure is reached. While the respiratory health effects of lead-containing smoke from lead smelting are relatively obvious symptoms, the impact of lead exposure on the brain is virtually invisible. As such, symptoms like the slow development of children or abdominal pain are usually not linked to lead poisoning by observers.

60% of the women reported no prominent health challenges in their 40% cited cases community, while the remaining tuberculosis, cholera, chest congestion, eye problems, and stomach problems. **Apart from one respondent, everyone in the sample said that they have not faced any health issues while working in ULAB recycling. However, the surveyors observed cases of**

blue lines among the gums and skin lividity

(bluish-purple discolouration) among the respondents, symptoms characteristic of chronic lead toxicity.

Three had faced accidents at work, such as touching or spilling of molten acid, heavy batteries falling on their feet, etc. **When presented with a list of symptoms that could suggest lead poisoning (e.g. acute abdominal pain, vomiting, constipation, fits and faints, anaemia, and gum deposits),**

three of the workers reported experiencing similar symptoms since working in ULAB recycling.

Three people had noticed similar symptoms in their families as well.

Three respondents have had children in the household within the last five years, and one of them has experienced a stillbirth in the family prior to the birth of their child. However, none of the workers surveyed had undergone blood tests or medical examinations since starting ULAB recycling work.

Only about half 1/2 of the sample was aware of the risk of lead poisoning posed by their occupation.

The surveyors cite anecdotes of a worker in the neighbourhood whose wife and child had died from symptoms similar to lead poisoning, and another worker whose child was recently born disabled. **However, all evidence of lead poisoning-related health challenges remains anecdotal, as neither the workers nor the medical system had ever connected their symptoms to lead poisoning, and no medical testing for lead poisoning had taken place.**

The key hospitals that served as touchpoints for the workers included Patna Medical College, the Indira Gandhi Institute of Medical Science, and other government hospitals.

Interviews with Doctors

Semi-structured interviews were held with three doctors in hospitals and clinics located in the vicinity of ULAB recycling hotspots. Snowball sampling was used to identify and approach respondents. The aim was to understand the level of awareness around lead poisoning in the medical system and the medical capacity to conduct blood lead level testing. The particular profile sought out for the interviews were OPD (Outpatient Department) doctors, as they are responsible for managing patient flow and serve as the first point of contact for patients arriving at the hospital.

When asked if they have treated battery recycling workers from nearby areas, all answered in the negative. Typically, when medical professionals collect details on medical history, the ULAB recycling workers would likely be unwilling to reveal their occupational background given that their operations are illegal. Additionally, the doctors would not have time, particularly during peak hours, to probe into their clinical history in depth.

All of the doctors noted that they frequently receive patients who exhibit symptoms characteristic of lead poisoning, like acute abdominal pain, vomiting, constipation, fits and faints, anaemia, gum deposits, etc. However, these symptoms are highly common and are associated with a variety of widespread illnesses like flus and viruses. Moreover, many individuals afflicted with lead poisoning do not show outward symptoms until blood lead levels become extremely high. **As such, none of the doctors had ever connected these symptoms or patients to lead poisoning. All of the doctors interviewed also indicated that awareness on the health impact of lead exposure in the medical system remains negligible.**

None of the hospitals surveyed had in-house equipment to perform blood lead level testing, and none of the doctors had ever recorded blood lead levels in patients. Chelation reagents, which are used to treat lead poisoning, were not available in any of the respondent hospitals as well. By many accounts, the Mahavir Cancer Sansthan is the only hospital in Patna with adequate equipment and training for blood lead level testing, namely an atomic absorption spectrometer. This is because they had previously conducted an assessment of the prevalence of elevated blood lead levels and risk factors among children and pregnant women in eight districts of Bihar.[51]

As such, if a battery recycling worker comes into one of the respondent hospitals with symptoms of lead poisoning, the OPD doctors would likely be unable to gain a complete picture of their medical history, would lack the necessary awareness of lead poisoning as an occupational hazard of ULAB recycling, would fail to link the root cause to their occupational background, and thus would not be equipped to offer the appropriate medical advice or treatment.

Interviews with Hospital Administrators

Semi-structured interviews were held with three hospital administrators to learn about the procedure followed by hospitals for the disposal of inverters or UPS systems, which use ULABs. Snowball sampling was used to identify and approach respondents. The respondent profile sought out included hospital operations managers, biomedical waste managers, hospital administrators, and chief medical officers (CMOs), who would know about the hospital's condemnation policy (institutional policy for the disposal of waste produced by the hospital).

Since hospitals require uninterrupted power supply, each hospital typically makes use of many inverters. Discussing whether hospitals themselves follow the proper protocol for the safe disposal of ULABs sheds light into the level of awareness around lead poisoning in the medical system itself.

One of the administrators was unaware about the procedure for the disposal of inverters of UPS systems in hospitals, whether their condemnation policy addressed this, or whether the hospital's condemnation policy for UPS systems was followed in practice. **Two of them indicated that the inverters were picked up by kabadiwalas (door-to-door garbage collectors). Additionally, all of the hospital administrators surveyed were unaware of the health impact of lead exposure or the proper procedure for ULAB disposal.** All of them agreed that there was an urgent need for mass awareness campaigns among hospital staff and stakeholders.

51. Lu, Y., Chandan, A. K., Mehta, S., Kushwaha, M., Kumar, A., Ali, M., and Kass, D. (2024). Assessment of prevalence of elevated blood lead levels and risk factors among children and pregnant women in Bihar, India. Environmental Research, 259, 119528. Link

This means that even the ULABs in the hospital inverters would likely reach the informal sector when disposed of through the kabadiwalas, further contributing to the issue of informal ULAB recycling in Bihar.

Conclusion

Few studies have delved into the qualitative experiences of ULAB recycling workers, and this report highlights the urgent need to expand such efforts. The findings from semi-structured interviews with 11 ULAB recycling workers in Bihar provide critical insights into the on-ground operations within the informal sector, highlighting the highly dangerous and covert nature of the occupation, wherein operations are often conducted in residential and mixed use areas, with poor ventilation, insufficient pollution control technology, little to no protective gear, improper waste management practices, and immensely high risk of lead exposure to workers and the members of their household, including pregnant women and children. The interactions also underscore the lack of regulatory compliance in formal ULAB recycling units, which operate under regulatory oversight but still exhibit worrying lapses in safety protocol.

Workers continue to stay within the informal ULAB recycling occupation for many years on end, given that they reap strong economic rewards and the widespread lack of awareness around lead poisoning, as a result of which they are unaware that many of the health challenges faced by themselves and their family could point to lead poisoning.

Moreover, the research sheds light on the lack of awareness around lead poisoning and the dearth of resources for blood lead level monitoring in key touchpoint hospitals in and around ULAB recycling hotspots. The lack of medical capacity for the appropriate diagnosis and treatment of lead poisoning in ULAB recycling hotspots is highly alarming.

These insights, though based on a small and non-representative sample, underscore the urgent need for comprehensive interventions to address the health, safety, and regulatory challenges in the ULAB recycling ecosystem in Bihar and the rest of India. With the continuous growth of the industry, there is a need to research and closely monitor market factors, production processes, and health impacts of the lead-acid battery industry. Determining the channels of lead exposure in the industry will have critical implications for preventive public health measures and risk reduction.

08 POLICY RECOMMENDATIONS

Some policy recommendations to mitigate this pressing issue include:

Improving the Regulatory Framework

01 Reducing or eliminating taxes on scrap batteries

One reason formal sector ULAB recycling is less cost-competitive than recycling in the informal sector is that they pay GST on scrap batteries. In India, the GST rate on the waste and scrap of primary cells, primary batteries, and electric accumulators is 18% (under HSN Code 8506), which formal sector retailers, recyclers, and remanufacturers are required to pay. Reducing or eliminating this tax would remove the artificial price advantage of illegal smelters and improve the economic viability of formal recycling.

Along similar lines, the GST Council has previously reduced the GST on electronic waste from 28 percent to 5 percent and on plastic waste from 18 percent to 5 percent, to promote collection and recycling. Joshi et al. (2021) at IIT Kanpur find that reducing tax on regulated recyclers can help the ULAB recycling business shift from the informal to the formal sector.

Brazil abolished taxes on recycled batteries, which shifted recycling activities into legal smelters. As higher volumes of LABs were produced (due to the higher quantity and lower cost of recycled lead), this policy change ultimately increased overall tax revenues. A compilation of global best practices in encouraging safe and environmentally-sound ULAB is presented in the appendix.

02 Institutionalise occupational guidelines and biological exposure indices for lead

The Occupational Safety and Health Administration (OSHA) guidelines require medical removal of a worker if a BLL of 50-60 µg/dL is reached, permitting them to return to work only after 2 consecutive measurements below 40 µg/dL. When it comes to airborne lead, OSHA has a 50 $\mu g/m^3$ permissible exposure limit. Under the CPCB's Standard Operating Procedure for safe ULAB recycling, State Pollution Control Boards/Pollution Control Committees (PCCs) are advised to prescribe the following standard: annual examination of blood lead levels, and medical removal and treatment for workers with BLLs higher than 42 µG/dL. There is a need to institutionalise guidelines on occupational health, including a blood lead level monitoring

52. Ragpickers Heave A Sigh Of Relief As GST On Recycling Waste Comes Down. October 10 2017. Swachh India NDTV. Link
53. Joshi et al. (2021). Impact of policy instruments on lead-acid battery recycling. IIT Kanpur. Link
54. Global Battery Alliance and the World Economic Forum. Consequences of a Mobile Future: Creating an Environmentally Conscious Life Cycle for Lead-Acid Batteries. Link

program and action threshold for workers in battery industries at a national level. However, these guidelines can only be followed given adequate medical capacity for blood lead level testing and treatment of lead poisoning near ULAB recycling units.

03 Mandating a reverse logistics system

Brazil mandated a reverse logistics system, wherein each stage of the supply chain returns ULABs to the previous one. An initial set of regulations established legal requirements, while the next set of laws (which began at a state level and then expanded nationally) set specific targets, implementation details, and reporting mechanisms.

Manufacturers and importers were required to show that they had collected and formally recycled ULABs equivalent to a large percentage of the ones sold (beginning at 75% of batteries sold and increasing incrementally over the years). Targeting these groups is effective because they are large entities by nature and require specific environmental licences to start operating, making them easy to monitor.

Retailers return ULABs to distributors, who send them to manufacturers, who deliver them to formal recyclers, who issue proof that allows manufacturers to satisfy their regulatory obligations. This system reduces transportation costs, as used batteries are collected at the same time new batteries are delivered. It also eases government control, as manufacturers are given the responsibility to report compliance. Technology (e.g. blockchain) can be leveraged to track the reverse logistics supply chain, with a penalty at every stage for those who fail to comply.

Improving Monitoring and Enforcement

01 Entrust monitoring and evaluation to a third-party managing entity

Brazil's ULAB reverse logistics process is partially managed by IBER (Instituto Brasileiro de Energia Reciclável), a third-party entity acting as an intermediary between the Brazilian battery industry and the government. IBER ensures members' compliance with the relevant regulations, and members are exempted from individually proving compliance each year. Given the limited regulatory and enforcement capacity in LMICs, third-party certification programs may be a viable option to improve compliance. Industry bodies in India, like the Indian Battery Manufacturers' Association could be enlisted to be such an intermediary.

02 Ensure adequate medical capacity for the diagnosis and treatment of lead poisoning

To ensure compliance with the CPCB SOP requiring regular blood lead level monitoring and medical removal of workers in case of high blood levels, the need of the hour is to remedy the critical lack of medical capacity for the treatment of lead poisoning, particularly in hospitals and clinics located near ULAB recycling hotspots. This would include targeted training programs for OPD doctors and other frontline healthcare workers, with a focus on recognizing symptoms of lead poisoning, a standardised protocol for collecting occupational history in regions where hazardous industries are prevalent, and proper referral practices to medical institutions with relevant facilities available. There is also a need to provide essential equipment and materials for the diagnosis and treatment of lead poisoning, such as atomic absorption spectrometers and chelation reagents in major hospitals.

03 Integrate collection by the informal sector with formal sector recycling

Informal economies provide valuable opportunities for low-income and marginalised populations. One strategy to engage the informal sector and take advantage of its strengths is to encourage informal operators to collect used batteries, and to facilitate their work, particularly in areas that lack formal collection processes and centres. Care should be taken to ensure that collected batteries are returned to formal sector recyclers and smelters. In many countries, the informal sector already serves as the primary channel through which batteries are collected. Gupt and Sahay (2015) find that successful extended producer responsibility for ULABs in India can be achieved by integrating the informal collection system with formal recycling, strengthening the upstream deposit-refund system.[55] Moreover, an auditable direct link between producers, distributors, and retailers can help ensure responsibility for sound end-of-life management.

04 Implement an awareness-raising public health campaign

Public awareness around the proper disposal of lead-acid batteries remains low. Many consumers are unaware of the environmental and health hazards posed by improper disposal, leading to the discarding of ULABs with regular household waste or their sale to kabadiwalas. A targeted awareness-raising campaign on the health impact of informal recycling to educate and engage consumers of lead-acid batteries, as well as health professionals and the industry, is the need of the hour. Moreover, battery workers should be sensitised on the negative health impacts of their occupation, and encouraged to adopt basic safety precautions: wearing gloves, eating in a separate mess area, changing clothes before going home, etc.

05 Improve the M&E Capacity of State Pollution Control Boards/Pollution Control Committees

State Pollution Control Boards (SPCBs) and Pollution Control Committees (PCCs) are statutory authorities constituted to implement the provisions of environmental laws and rules, with a predominant role in monitoring of compliance by stakeholders, e.g. manufacturers, dealers, etc. A performance audit of SPCBs and PCCs conducted by CPCB in 2019-20 revealed that these entities were not adequately equipped with infrastructure, trained staff, or law enforcers. Shortage of manpower was identified as the chief cause of under-performance, with about 46% of posts vacant and skeletal staff in many SPCBs.[56] SPCBs are required to submit annual compliance status reports to the CPCB, but very few do so.[57] In practice, stakeholders indicate that CPCB helplines often go unanswered and emails are not responded to, forcing

55. Gupt, Y., & Sahay, S. (2019). Waste management and extended producer responsibility. Econ Polit Wkly, 54, 35. Link
56. Central Pollution Control Board, 2019 – 20. Brief Note on Strengthening of State Pollution Control Boards (SPCBs) / Pollution Control Committees (PCCs). Link
57. Central Pollution Control Board, 2016. Status Review Report on Implementation of Batteries (Management and Handling) Rules, 2001 (as amended thereof). Link

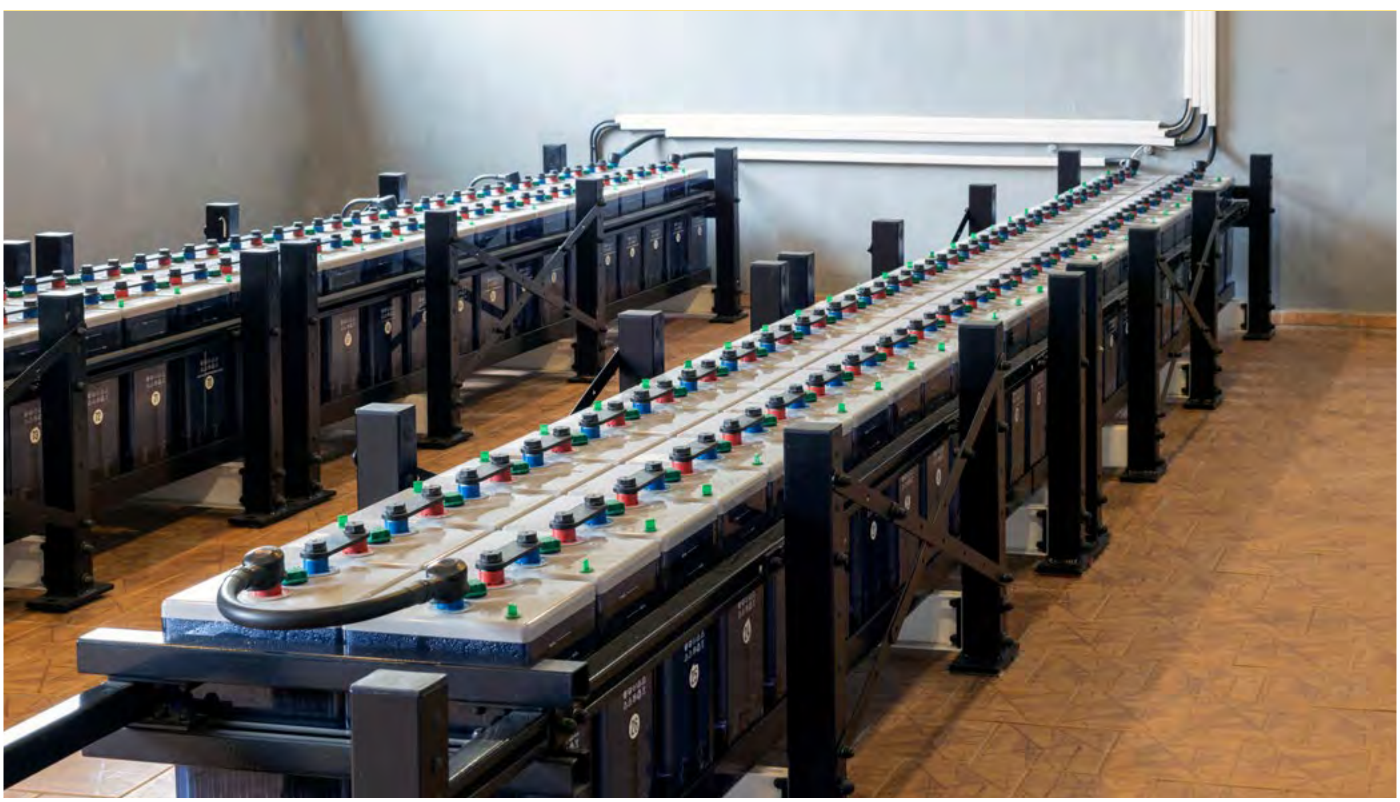
aggrieved parties to travel to their offices in person. Capacity-building in SPCBs and PCCs would help them execute their monitoring and enforcement responsibilities more effectively, and emerge as the relevant, visible, and accountable government authorities to crack down on the informal ULAB recycling issue.

06 Initiate cluster development for ULAB recyclers

In line with the MSME Cluster Development Programme (MSE-CDP), a targeted cluster development initiative could be launched for ULAB recyclers, to relocate recycling activities from residential to industrial areas and bring them within a centralised operation system. Consolidating small and fragmented recycling units into a single cluster would make it easier to conduct regular blood lead level monitoring, awareness workshops on lead poisoning, technology and knowledge transfer, collective applications for CPCB registration, and regulatory oversight, bringing informal recyclers into the formal sector while protecting livelihoods. This will also drive economies of scale, efficiency in operations, and improve the overall economic viability of formal recyclers. Production-Linked Incentives and subsidies can play a role in accelerating the development of such infrastructure. Moreover, a co-operative funded scheme can be considered for producers to pool funds in collecting ULABs and ensuring that they are delivered safely to certified recycling facilities.

07 Identify and remediate contaminated sites

ULAB recycling is a primary contributor to lead-contaminated soil. Communities that are already contaminated will remain contaminated without adequate remediation, creating exposure for generations to come.



Soil remediation interventions and household cleaning near abandoned ULAB recycling sites have proven effective in reducing lead exposure.[58]

08 Improve access to alternative livelihoods

Our interactions with large-scale formal sector recyclers in India indicate that they rotate workers from high-exposure areas to low-exposure areas when their BLL is measured above 50 µg/dL, to meet the medical removal requirement of OSHA standards. Similarly, informal ULAB recyclers would experience lower BLLs and fewer negative health impacts from reducing the cumulative duration of their exposure to lead, by taking periodic breaks from the high-exposure activity of ULAB recycling. A safer supplemental or alternative livelihood option would help them diversify their income streams and reduce their dependence on informal ULAB recycling, potentially enabling a shift away from this dangerous occupation in the long term. ULAB recycling workers should be sensitised to the alternative livelihood opportunities available in their communities, and connected with relevant government schemes providing re-skilling options, such as the Bihar Skill Development Mission, Jan Shikshan Sansthans, Industrial Training Institutes (ITIs), etc.

58. Rahman, M., et al. (2024). Effectiveness of soil remediation intervention in abandoned used lead-acid battery (ULAB) recycling sites to reduce lead exposure among the children. Science Direct, 102772. Link

09

APPENDIX: GLOBAL BEST PRACTICES

This section explores the laws, regulations, and initiatives undertaken by Germany, Bangladesh, USA, South Korea, Brazil, Sweden and the European Union (EU) to address the issue of ULAB recycling. These countries have been selected for their implementation of best practices in ULAB recycling and distinctive legal frameworks.

It must be noted, however, that many developed countries send their battery scrap to LMICs such as India and Bangladesh for ULAB recycling, ensuring that their citizenry does not work with the dangerous metal, while also achieving their recycling targets without any damage to their environment. However, the limited recycling they do perform within their borders is strictly regulated and monitored.

Germany

The country's robust legal framework, strict oversight by environmental authorities, and public awareness and participation help ensure that lead battery recycling is conducted safely and in accordance with the law.[59]

German laws, such as the **Batteries Act (BattG)**[60] and the **Circular Economy Act (KrWG)**[61]**,** impose rigorous requirements on the collection, transport and recycling of batteries. These laws mandate proper handling and recycling by licensed facilities. BattG[62] implements the EU Battery Directive (2006/66/EC), into national law, thereby establishing the legal framework for managing batteries and accumulators in Germany. While BattG is similar to the Indian law, the Circular Economy Act of Germany is unique. It aims to promote a sustainable and resource-efficient economy by promoting a circular economy. The Act, besides listing down a waste hierarchy, also provides for recycling targets and public and private sector collaboration for innovation and research. German environmental authorities, such as the Federal Environment Agency (Umweltbundesamt - UBA) and regional environmental agencies, actively monitor and enforce compliance with waste management regulations. Regular inspections and audits help ensure adherence to legal standards.[63]

There is a high level of public awareness regarding environmental issues in Germany. Consumers are informed about the importance of proper battery disposal and the availability of collection points, reducing the likelihood of batteries ending up in informal recycling channels.[64] German schools frequently incorporate recycling education into their curriculum. By exposing students to the significance of recycling from an early age, a sense of responsibility is fostered in the younger generation, thereby cultivating a culture of sustainability.[65]

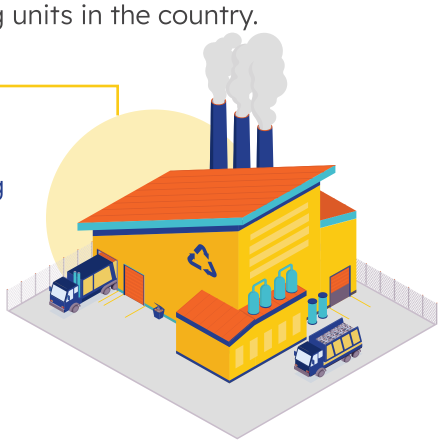
59. (Germany recycles more than any other country, 2017)
60. (EU Battery Regulation 2023 BATT2 – Important for Online Commerce, 2023)
61. (Circular Economy Act, 2012)
62. (What does the Battery Act (BattG) Germany regulate?, 2023)
63. (UBA, 2023)
64. (What Matters, Recycling, 2018)
65. (Why is Germany the World's Most Effective Recycling System, 2023)

Bangladesh

Before the release of the landmark UNEP[66] report on ULAB recycling in Bangladesh, there were only 6 formal recycling units in the country.

6

formal recycling units in the country.



Though there was a procedure for the collection of batteries by the formal recycler, it was not favoured by the people as informal recyclers paid more for used batteries. Across Bangladesh, 22,480 individuals were engaged in the battery recharging or recycling establishments, and

25%

of them were child workers aged between 5 and 17 years.

Moreover, Bangladesh was believed to house more than 1,100 informal and illegal ULAB recycling operations, and the average concentration of lead in children's blood in Bangladesh was estimated to be among the highest in the world at approximately 8 µg/dL[67].

66. (Assessment of Informal Used Lead-acid Battery Recycling and Associated Impacts in Bangladesh, UNEP, 2020)
67. Ibid

The UNEP report recommended that the recycling of used lead-acid batteries (ULABs) is too hazardous to be conducted outside of licensed, regulated, and environmentally responsible facilities, even though informal economic activities offer crucial opportunities for low-income and marginalised populations. It noted that informal operations lacked the necessary equipment, sanitary controls, standardised processes and monitoring to prevent occupational and public lead exposures, being rudimentary and secretive operations devoid of basic safety measures. It recommended that shifting ULAB recycling to the formal sector in Bangladesh would ensure environmentally-sound practices and enhance the health and prosperity of the population.

As a result of this report, the Hazardous Waste (E-waste) Management Rules, 2021 was enacted. The legislation aims to ensure environmentally-sound e-waste management practices and to mitigate the health and environmental risks associated with the improper handling of such waste. It champions the principle of Extended Producer Responsibility and encourages the transition of informal recyclers to the formal sector by providing training and support to adopt safer and more efficient recycling practices. It further implements monitoring systems to ensure adherence to environmental standards, and includes stricter penalties for non-compliance to enforce the regulations effectively.

While the law is similar to that of India, thanks to the UNEP report, mass awareness and dissemination of information around lead poisoning (due to informal ULAB recycling) has taken shape to a much greater extent.

European Union

The EU has implemented stringent regulations and directives to manage ULABs effectively. The Battery Directive (2006/66/EC) mandates high recycling rates for lead-acid batteries and the End-of-Life Vehicles (ELV) Directive also supports the collection and recycling of these batteries. The regulatory framework aims to minimise the environmental and health impacts of batteries and accumulators by promoting their proper collection, treatment, recycling, and disposal. It restricts the use of hazardous substances like Lead, Mercury, and Cadmium, sets targets for collection and recycling rates, and mandates producer responsibility for financing waste management. The directive also emphasises consumer information and participation in collection schemes, ensures environmentally-sound end-of-life management, and requires member states to report compliance and enforce measures. According to EU Regulation 493/2012 recycling facilities need to report the recycling efficiency of the batteries that they receive from producers in the EU.[68]

Lead is one of the most recycled metals and around

99%

lead-acid battery recycling rate has been achieved in the EU[69].

[68] (Producers responsibility for batteries, 2024)
[69] (Bergsöe completes the cycle, 2024)

USA

In the United States, the recycling of ULABs is a well-established process. The Environmental Protection Agency (EPA) promotes recycling by offering two alternative management standards for lead-acid batteries. These batteries can be managed as "universal waste" under 40 CFR Part 273 or according to the specific alternative standards outlined in 40 CFR 266, Subpart G. The relevant regulations and best practices are as follows:

01 **Resource Conservation and Recovery Act (RCRA):** The RCRA[70] the framework for the proper management of hazardous and non-hazardous provides us solid waste. Under the RCRA, used lead-acid batteries are classified as "universal waste," which simplifies the regulatory requirements for handling, transporting, and recycling these batteries.

02 **Battery Act (Mercury-Containing and Rechargeable Battery Management Act):** This act[71] facilitates the recycling of rechargeable batteries, including lead-acid batteries. It details steps for recycling, thus making it easier to manage.

03 **Environmental Protection Agency (EPA) Guidelines:** The EPA provides guidelines[72] and oversees the implementation of federal laws regarding battery recycling to ensure environmental protection and public health.

04 **Occupational Safety and Health Administration (OSHA):** The OSHA Lead Standard was introduced in 1978 and applies to all workers in general industries where an employee may be occupationally exposed to lead.[73] OSHA sets a Permissible Exposure Limit (PEL) for lead in workplace air of 50 micrograms per cubic metre of air (calculated as an 8-hour time-weighted average), and an Action Level of 30 micrograms per cubic metre.[74] If the permissible exposure limit is exceeded, they must provide high-efficiency HEPA-equivalent respirators, dedicated changing rooms, a lunchroom with clean, filtered air, shower facilities, and personal protective equipment, which may include face shields, vented goggles, and disposable shoe coverlets, all of which the employer is responsible for cleaning and disposing. These standards are globally recognized as benchmarks.

The EPA has also provided a detailed step-by-step guide75 on the proper methods for handling, storing, packaging, transporting, recycling and disposing of waste in landfills, as well as the necessary personal protective equipment (PPE). In fact, an entire section76 on the EPA website cites information on lead poisoning, sources, and its prevention for the sole purpose of dissemination.

70. (Resource Conservation and Recovery Act (RCRA) Compliance Monitoring, 2024)
71. (The Mercury Containing and Rechargeable Battery Management Act, 2024)
72. (Waste lead-acid batteries, 2023)
73. (Occupational Standards and Guidelines for Lead, 2013)
74. (Occupational Health and Safety Standards)
75. (Incident Waste Decision Support Tool (I-WASTE DST), 2023)
76. https://www.epa.gov/lead

Sweden

In Sweden, the robustness of law directly addressing the recycling of batteries has made the ecosystem efficient. In order to implement the EU Battery Directive (2006/66/EC), Sweden enacted and enforced a law (SFS 2008:834) instituting the producer's responsibility for the collection of batteries; the ordinance mandates the collection of at least 95% of all lead-acid batteries.[77] This target has been consistently achieved by the lead-acid battery industry in recent years. The highlight of this law is that a producer can establish an individual collection scheme for waste batteries, provided certain requirements are met, instead of joining a national collective collection scheme.[78] There are collective schemes and systems for lead batteries. The Swedish Environmental Protection Agency (Naturvårdsverket) also elaborates in detail the recycling process of ULABs on its website, thereby educating the laymen as well.

South Korea

Since South Korea prohibited the landfilling of food waste in 2005 and subsequently banned the ocean dumping of its liquid byproduct, leachate, in 2013, the country has implemented an extensive program that recycles nearly everything.[79] Since the early 1990s, its world-class solid waste management (SWM) legislation and initiatives have significantly contributed to waste reduction. These measures include a volume-based waste disposal fee (VBWF) system, a deposit refund system, extended producer responsibility (EPR), and bans on problematic plastic items and packaging.80 In 2023, the battery recycling market reached an estimated value of USD 202.47 million. It is projected to grow at a compound annual growth rate (CAGR) of 6% from 2024 to 2032. This growth is fueled by increasing research on the uses and applications of second-life batteries and the rising demand for sustainability in the battery manufacturing industry.[81]

While South Korea has typical laws in place such as the Wastes Control Act[82] and Korea Toxic Chemicals Control Act (TCCA)83, the highlights are the Resource Circulation Act84 and EPR Schemes/Policies. The Resource Circulation Act[85] in South Korea, implemented in 2018, aims to promote sustainable waste management and resource recycling. It seeks to reduce waste generation, enhance recycling rates and minimise environmental impact. Key

77. https://blybatteriretur.se/english/
78. https://www.naturvardsverket.se/en/guidance/extended-producer-responsibility-epr/producers-responsibility-for-batteries/#E-1340467067
79. https://www.latimes.com/world-nation/story/2023-08-24/how-south-koreans-composting-system-became-a-model-for-the-world#:~:text=Since%20South%20Korea%20banned%20land,in%20the%20case%20of%20Nanji
80. https://www.downtoearth.org.in/news/waste/ten-zero-waste-cities-how-seoul-came-to-be-among-the-best-in-recycling-68585
81. https://www.expertmarketresearch.com/reports/south-korea-battery-recycling-market/requestsample?trk=article-ssr-frontend-pulse_little-text-block
82. https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=43284&type=part&key=39#:~:text=To%20the%20extent%20possible%2C%20wastes,of%20wastes%20shall%20be%20restrained.&text=Wastes%20shall%20be%20recycled%20rather,the%20improvement%20of%20resource%20productivity.
83. https://www.cirs-reach.com/KoreaTCCA/Korea_Toxic_Chemicals_Control_Act_TCCA.html#:~:text=The%20current%20Toxic%20Chemical%20Control,and%20response%20to%20chemical%20accidents.
84. https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=51210&type=part&key=39
85. http://www.kora.or.kr/eng/coreBusiness/eprPolicies.do

measures include waste reduction, recycling, EPR, incentives and penalties. The act aligns with South Korea's broader environmental goals of transitioning to a circular economy and reducing reliance on landfills and incineration.[86] Under the EPR schemes, producers and importers pay recycling support fees, which are allocated to recycling companies based on the quantity and volume of recyclable items they handle. The Korea Resource Circulation Service Agency (KORA) manages these fees and subsidies. This system incentivises producers to reduce waste and helps prevent environmental pollution caused by packaging waste. By doing so, it promotes a resource circulation society and sustainable development.[87]

Brazil

Brazil is often cited as a success story in transitioning from majority-informal to majority-formal ULAB recycling, having eliminated at least half of its informal sector through a series of innovative market-driven policies between 2008 and 2019, achieving 75% formal sector recycling by 2022. Notably, Brazil is also an LMIC like India.

Brazil was the first country in Latin America to regulate the disposal and treatment of batteries,[88] by enacting The National Solid Waste Policy (PNRS), established by Law No. 12,305/2010.

Key features of the policy include the principles of :

01 Shared responsibility among various sectors of society

02 Promotion of waste reduction

03 Recycling and Reuse

04 Integration of informal waste collectors into the formal waste management system.

Regarding battery recycling, the policy mandates the implementation of a reverse logistics system, thereby contributing to a circular economy.[89]

With initiatives like reverse logistics by Green Eletron and ABINEE's Batteries Collection Program, Brazil has been quite successful in ensuring the

86. Ibid 33
87. Ibid 34
88. Espinosa, D. C. R., Bernardes, A. M., & Tenório, J. A. S. (2004). Brazilian policy on battery disposal and its practical effects on battery recycling. Journal of power sources, 137(1), 134-139.
89. https://braziliannr.com/brazilian-environmental-legislation/law-no-12305-brazilian-national-policy-solid-waste/#:~:text=Art.,responsibilities%20and%20applicable%20economic%20instruments.

recycling of ULABs. A reverse logistics initiative is being spearheaded by Green Eletron[90] in Brazil. Over the years, Green Eletron has collaborated with over 64 electronics and battery brands, facilitating the recycling of over 520 tons of electronic waste. Additionally, it established 173 disposal units across 69 cities in São Paulo state and the Federal District, and then expanded to 500 units across 13 states.[91] Thus, Brazil has been quite successful in spreading awareness about battery recycling. The ABINEE's Batteries Collection Program adopts reverse logistics for portable batteries and batteries for domestic use. Initiated in November 2010, this program complies with CONAMA Resolution 401/2008 and NSWP Law 12,305/2010.[92] ABINEE runs educational campaigns through various media channels, conducts workshops, and engages in partnerships with retailers to create collection points. They provide information on the environmental impacts of improper disposal and the benefits of recycling.[93] These efforts help immensely in spreading awareness around lead poisoning.

Understanding the Used Lead Acid Battery (ULAB) Recycling Ecosystem in India

Key Informant Interview Guide

Respondent Profile: Informal Used Lead Acid Battery Recycling Workers

Objective of the interaction:
The purpose of the interaction is to learn about used lead acid battery recycling in the informal sector, including the market dynamics, unit economics, safety and waste management protocol, and health issues faced by workers and their community.

Interviewer instructions:

- This interview guide serves as a **checklist for the interviewer** so that he/she does not miss out on any important area of discussion.
- At the outset share briefly the purpose of the research study with details of the proposed research sites as well as the methodology being followed. Give time for any clarifications that may be sought.
- Explain the ethical procedures being followed.
- Seek consent for the interview using the consent form.
- It would be better to have 2 people to interview so that as one is facilitating the discussion the other can take notes.
- Record the interview if the respondent agrees.
- Ask all questions in an informal manner and in the flow of the conversation while interviewing.
- Kindly prompt if necessary, rather than simply follow the script.

Interaction details:

Moderator name	
Note-taker name	
Date of the interaction	
Location name	
Block name	
District name	
Duration of the interaction	Start time: End time:

Respondent demographic information and contact details:

- Name:
- Age:
- Gender:
- Address:
- Mobile Number (if available):
- Email ID (if available):

Discussion guide:

Introduction and warm up

- Since when have you been working as an informal recycler?
- What does the typical day of an informal recycler look like?
- What are some of the main health challenges for you, and in your village / area?
- Are you from Patna, or have you migrated here from elsewhere?

Overview of the recycling unit

- Do you own the recycling unit?
- What is the typical age range and gender of employees in the unit?

- Does the unit have a formal licence or registration with the Central Pollution Control Board? [If owner of unit]
- If yes, does it file reports or returns on a regular basis? [If owner of unit]
- Has the unit ever received visits from local law enforcement agencies / authorities, e.g. police or health inspectors? If so, when and how often?
- What kind of raw materials do you receive for recycling? (Select all that apply)
    - o Wet cell batteries (Flooded lead acid batteries with liquid electrolyte)
    - o Dry cell batteries (Sealed or maintenance free batteries without liquid electrolyte)
    - o Lead dust
    - o Lead bricks
    - o Other lead-containing waste from industries
- Which of the following tasks are performed by the recycling unit? (Select all that apply)
    - o Dismantling and separating battery components
    - o Smelting lead
    - o Refining lead
    - o Battery making
- What are your biggest sources of raw materials for recycling?
    - o Battery dealers or manufacturers
    - o Traders
    - o Scrap dealers / Kabadiwalas
    - o Workshops
    - o Collection centres
    - o Non-battery industries
    - o Consumers
    - o Others: _____
- What kind of smelting is performed? [Can be filled out by surveyor based on observation]
    - o Backyard smelting
        - ▪ *Smelting in backyard or kitchen, manual separation of battery components through hammers, no protective gear, waste thrown in soil or drains, highly polluting*
    - o Low standard industrial smelting
        - ▪ *Smelting in chambers or pits / bhattis (open or closed), manual separation through hammers, little to no protective gear, waste thrown in soil or drains, highly polluting*
    - o High standard industrial smelting
        - ▪ *Smelters with air handling systems to filter toxic lead dust, carried out in a factory environment, separator machines to dismantle battery components, proper waste management, protective gear used, environmentally safe*

Market Dynamics and Unit Economics

- Per kilogram on average, how much do you buy the raw material (used lead acid battery) for?
- How frequently do you receive the raw material, and approximately how many kilograms at a time?
- On average, how many kilograms of recovered lead / how many units of recycled batteries do you sell each month?
- Per kilogram on average, how much do you sell the recovered lead / recycled battery for?
- On average, how much are your costs of running the recycling unit each month?
- Approximately what percentage of the lead is recovered in the recycling process?
- Per month on average, what is your income?
- Have you considered adopting more protective wear and technology towards safe and environmentally-sound recycling? Are you willing to invest in more equipment and technology? [If owner of unit]

Waste Management and Safety Protocol

- What do you do with the battery electrolyte / acid / liquid? Where do you pour it?
- What do you do with the other battery components (e.g. plastic casings, separators, lead grids) and furnace residues?
- Do you use any protective wear?

    - Gloves
    - Special footwear, e.g. rubber boots
    - Breathing masks
    - Protective clothing (on top of daily wear)
- Do you typically change clothing after shifts?
- Where do you eat your meals - close to the unit's premises, or in a separate area?
- Do you have other jobs?
- Do you perform this job year-round or take seasonal breaks?
- If you were not doing this job, what alternate job(s) would you do?
- Who are the members of your household (i.e. those who sleep in the same area and eat meals with you)? Do they come to the recycling unit?

Health Issues

- Have you faced any health issues while working in the unit? Do you notice an improvement in your health when you are on break from work?
- Are you aware of the negative health impact / lead poisoning risk of informal used lead acid battery recycling?
- Have you ever suffered accidents at work, e.g. touching or spilling molten acid, heavy batteries falling on feet during onloading or offloading, etc.?
- Have you had children in the household in the last five years? Have there been any stillbirths or other reproductive health issues?
- Have you noticed the following symptoms in yourself since working in the recycling unit: acute abdominal pain, vomiting, constipation, fits and faints, anaemia, gum deposits?
- Have you done any medical examinations and blood tests for any illnesses since you joined this recycling unit? Please elaborate on the tests and their results.
- Have you noticed the following symptoms in your family since working in the recycling unit: acute abdominal pain, vomiting, constipation, fits and faints, anaemia, gum deposits?
- For regular check-ups and/or health issues, which hospital(s) do you go to in the area?

Thank the respondent for their time

Understanding the Used Lead Acid Battery (ULAB) Recycling Ecosystem in India

Key Informant Interview Guide

Respondent Profile: Hospitals / Clinics Located Near Informal Used Lead Acid Battery (ULAB) Recycling Hotspots

(Doctors + Hospital Operations Managers)

Objective of the interaction:
The purpose of the interaction is to learn from doctors about used lead acid battery (ULAB) recycling in the informal sector, including the health issues faced by the workers and their community. Another aim is to learn about the procedure followed by hospitals for the disposal of inverters or UPS systems (which use ULABs).

Interviewer instructions:

- This interview guide serves as a **checklist for the interviewer** so that he/she does not miss out on any important area of discussion.
- At the outset share briefly the purpose of the research study with details of the proposed research sites as well as the methodology being followed. Give time for any clarifications that may be sought.
- Explain the ethical procedures being followed.
- Seek consent for the interview using the consent form.
- It would be better to have 2 people to interview so that as one is facilitating the discussion the other can take notes.
- Record the interview if the respondent agrees.
- Ask all questions in an informal manner and in the flow of the conversation while interviewing.
- Kindly prompt if necessary, rather than simply follow the script.

Interaction details:

Moderator name	
Note-taker name	
Date of the interaction	
Name of hospital	
Location name	
Block name	
District name	
Duration of the interaction	Start time: End time:

Respondent Profile: Doctors

Respondent demographic information and contact details:

- Name of respondent:
- Designation:
- Address:
- Mobile Number (if available):
- Email ID (if available):

Discussion guide:

Occupational Health of Battery Recycling Workers

- Have you treated battery industry workers, in manufacturing or recycling, from nearby areas / from elsewhere?

- What is the typical profile of these patients in terms of age range, gender, and years of work?
- Do they often exhibit symptoms of lead poisoning: acute abdominal pain, vomiting, constipation, fits and faints, anaemia, gum deposits, etc.?
- Is there awareness on the health impact of lead exposure?
- Have you recorded blood lead levels in these workers or the local community?
- If so,
    - Do you have in-house equipment to perform blood lead testing? What kind of testing facilities do you have?
    - Approximately what is the average blood lead level (BLL) among the workers? What is the average blood lead level in the community?
    - Are average blood lead levels higher than usual in these workers? Are average blood lead levels higher than usual in the community?
    - What is the highest blood lead level recorded?

Thank the respondent for their time

Respondent Profile: Hospital Operations Managers / Biomedical Waste Managers / Hospital Administrators / Chief Medical Officers (CMOs)

Respondent demographic information and contact details:

- Name of respondent:
- Designation:
- Address:
- Mobile Number (if available):
- Email ID (if available):

Discussion guide:

Procedure for UPS Disposal

- What is the procedure for the disposal of inverters or UPS (uninterrupted power supply) systems in hospitals? Does hospital condemnation policy typically address this?
- Is hospital condemnation policy for UPS equipment followed in practice?
- Are the batteries in UPS systems typically sent back to the battery manufacturer, given to formal recyclers, given to informal recyclers, sold to kabadiwalas, incinerated, etc.?
- Approximately how many UPS devices are present at a time?
- Is there awareness on the health impact of lead exposure?
- What kind of intervention (from the government, etc.) can promote the safe recycling of lead acid batteries by the hospital sector?

Thank the respondent for their time

Informed Consent Form

Title of Research Study: Understanding the Used Lead Acid Battery (ULAB) Recycling Ecosystem in India

Principal Investigator:

Dr. B. Dinesh Kumar, Advisor of the India Lead Elimination Action Project, Pahle India Foundation & Scientist G -Director Grade (Former)-ICMR- National Institute of Nutrition, HYD

Co-Investigators:

Ms. Ankeetaa Mahesshwari, Associate Fellow, Pahle India Foundation
Ms. Shreya Ganguly, Research Associate, Pahle India Foundation

Name of Organizations: Pahle India Foundation and Vital Strategies

Name of Sponsor: Open Philanthropy

PART I: Information Sheet

Study Purpose

The study is to learn about used lead acid battery recycling in the informal sector.

Procedures

If you volunteer for this study, we will request you to respond to a few questions. It would take approximately 20 minutes of your time to answer the questions.

Risks and Benefits

There are no foreseeable risks to participating in this study. If you are not comfortable about answering any of the questions, you will not be forced to respond. The study is for purely informational purposes; it doesn't offer any immediate benefit to you. The research study is designed to benefit society by gaining new knowledge.

Cost of Participation
We will not provide any compensation to you to participate in this study.

Confidentiality

The information gathered from you will be strictly confidential and only for research purposes. We will NOT publish your name, phone number, or any personal information. Your answers will be kept secure and will be combined with several other respondents in a summary report. The interview will be recorded and a transcript will be produced. The transcript of the interview will be analyzed by the Principal Investigators and colleagues. Only the research team will ever know that you participated in this study or your answers. The researchers may publish documents that contain direct or indirect quotations by you. Any quotations from the interview will be made anonymous so that you cannot be identified. Your name will not be published and a made-up name (pseudonym) will be used instead.

Sharing the Results

All or part of the content of the interview may be published in academic papers, policy papers, news articles, etc. However, no personal information will be published; only summary results will be published.

Rights and Responsibilities of Participants

As a subject in this study, you will have certain rights and responsibilities, including the following:

Rights of Research Participant

- Right to voluntary participation in research.
- Right to know about the Ethics Committee and its responsibilities towards protecting rights, safety and well-being involved in a research project, and to provide public assurance of that protection.
- Right to information about the Research Study in a local language.
- Right to refuse participation or withdraw participation at any point in the study without disclosing any reason.

Responsibilities of Research Participant

- To provide correct and complete demographic information including full name, age, address, telephone number and e-mail ID (if available).
- To be compliant with research protocol and procedures.
- To ask questions when he/she does not understand the research study team, or other team members when they talk about the procedure.

Right to Refuse or Withdraw

Your participation in this study is voluntary. You may decide not to participate or you may stop your participation at any time, without penalty.

Contacts for Questions, Complaints, Concerns

If you have any questions or requests for information relating to this research study or your participation in it, or if you want to voice a complaint or concern about this research, you may contact:

Name: Ms. Neera Bali, Director of Administration, Pahle India Foundation

Statement by the Researcher / Person taking Consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands that the following will be done.

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this consent form has been provided to the participant.

Name of Researcher / Person taking Consent (printed): ______________________________

Signature of Researcher / Person taking Consent: ____________________________________

Date: ________________________________
(Day/month/year)