



Toxics Link
for a toxics-free world

DEAD AND BURIED

A SITUATION ANALYSIS OF THE
BATTERY WASTE MANAGEMENT
IN INDIA



A study by Toxics Link

ABOUT TOXICS LINK

Toxics Link is an Indian environmental research and advocacy organization set up in 1996, engaged in disseminating information to help strengthen the campaign against toxics pollution, provide cleaner alternatives and bring together groups and people affected by this problem.

Toxics Link's Mission Statement - "Working together for environmental justice and freedom from toxics. We have taken upon ourselves to collect and share both information about the sources and the dangers of poisons in our environment and bodies, and information about clean and sustainable alternatives for India and the rest of the world."

Toxics Link has a unique expertise in areas of hazardous, medical and municipal wastes, international waste trade, and the emerging issues of pesticides, Persistent Organic Pollutants (POPs), hazardous heavy metal contamination etc. from the environment and public health point of view. We have successfully implemented various best practices and have brought in policy changes in the afore mentioned areas apart from creating awareness among several stakeholder groups.

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1. Introduction

In the modern world, batteries have become ubiquitous. They are used in variety of products and devices ranging from cars to mobiles, laptops, watches, television remotes, toys, medical devices and inverters. It is difficult to be not using some kind of charge storing device or battery in the current way of living. Its usage is across all ages and economic groups and is spread from home to office to institutions to industrial areas. Battery technologies are an essential part of the new advances in sectors such as electric vehicles (EVs), electronic devices and battery energy storage for renewable energy. The increasing reliance on battery storage is driving enormous demand – overall, globally battery applications are expected to become a \$90 billion-plus market by 2025, up from \$60 billion in 2015¹.

Batteries, though adding a lot of value to our lives, have environmental impacts at the end of their life, if not managed properly. Depending on the type (see section 1.1), batteries may contain cadmium, nickel, lead, mercury, copper, zinc, manganese, lithium, or potassium. When end-of-life batteries containing toxic and hazardous chemicals are not recycled or disposed of properly, they can pose serious environmental and health risks through a number of contaminations. In poorly managed landfills, batteries have the potential to leach toxic heavy metals such as lead, mercury and cadmium into the surrounding soil, surface and groundwater.

GLOBAL BATTERY MARKET

Every year over 15 billion batteries are produced and sold worldwide. According to The Freedonia Group, a Cleveland-based industry research firm, the world demand for primary and secondary batteries is forecasted to grow by 7.7 percent annually, amounting to US\$120 billion in 2019. Many are non-rechargeable which are discarded after a single use.

The Indian Battery market is huge owing to the vast population as well as increasing dependence on technology-driven products. In a vast country where meeting power demand of the ever-increasing population is a huge challenge, constant efforts and

¹ Arthur D Little, Future of batteries Winner takes all, 2018. Available at http://www.adlittle.com/sites/default/files/viewpoints/adl_future_of_batteries-min.pdf

innovations are being made to generate and store power. Though largest consumption of batteries in India is in automotive industry (lead acid batteries), the scientific and technological advances in other spheres has led to manifold increase in consumption of other types of batteries as well. In recent times there is significant focus on renewable energy, leading to surge in demand for batteries by this sector.

Though batteries like the ones used in mobiles or automobiles or storage for solar energy have longer lifespans, smaller batteries used in flashlights or clocks or remotes have relatively shorter usage life, meaning that they join the waste stream quicker. Batteries recycling and disposal has been a critical issue globally, but the concern in India is probably greater as here the small battery market is dominated by single use batteries or the primary cells, in comparison to most other countries where rechargeable batteries dominate. In India, huge numbers of used or spent batteries get discarded with household waste as there is little or no monetary value attached to it.

Though there has been some focus in the country on end of life lead acid batteries, little work has been done to understand the quantum of the smaller battery wastes generated in the country and its fate or its impact on environment. This is certainly of concern as the country has no infrastructure currently for its collection and treatment. While there are regulations in India for managing lead acid batteries, currently it has no frameworks for regulating the recycling and disposal of batteries (also called 'pencil cells' or 'dry cells'). The current Municipal Waste Rules, 2016 does include batteries as part of domestic hazardous waste, but there are no collection systems or recycling facilities to manage these batteries, generated in millions annually. Lack of scientifically designed landfills in the country also adds to the concern of leaching of toxic materials from the spent batteries. Apart from the toxicity issue, the used or spent single-use batteries are also an issue of concern as they contain many non-renewable resources and landfilling them would mean losing out on those resources.

1.1 TYPES OF BATTERIES

Small batteries (also termed as Household batteries) are commonly dry cell batteries where the electrolyte is an immobilized paste. Compared to the wet cell batteries, dry cells can be used in any portable device as there is no chance of spilling due to free fluid. Dry cells are also named according to their size, like, D, C, AA, AAA, and N and have different applications.

Small batteries are divided into two large categories, **primary** and **secondary** batteries.

Primary or non-rechargeable batteries are disposable because their electrochemical reaction cannot be restored. Once the cell completes reaction converting chemical energy to

electrical energy, it gets discharged changing its components irreversibly. These include zinc carbon batteries, zinc chloride, alkaline batteries, button cell batteries and lithium batteries. They are the most common household batteries often used in torches, toys, smoke detectors, watches, calculators, hearing aids, radios and remote controls.

Secondary or rechargeable batteries on the other hand have reversible electrochemical reaction. Also called the storage battery, after discharging the elemental materials, it can be charged back to an approximate original state by applying external current source in the opposite direction. Recharging can be done until the electrode materials last. They are available as freestanding units or as built-in components of rechargeable devices. These include nickel cadmium (Ni-Cd), sealed lead-acid (Pb), nickel metal hydride (Ni- MH), and lithium ion (Li- Ion). Nickel Cadmium is the most common type of rechargeable battery. Given below are some common types of batteries and their uses.

Table 1: Common Types of Batteries, their Usage & Compositions

Battery Types	Common Usages	Electrodes	Electrolyte
Alkaline	CD, MP3 players, toys, camera, flash lights, remote controls	Manganese dioxide + zinc	Potassium Hydroxide
Carbon Zinc	Clocks, radios, smoke alarm	Manganese dioxide + zinc	Zinc chloride
Lithium Coin	Calculators, electronic organizers	Metallic Lithium + Manganese Dioxide/ Carbon Monoflouride	Mixture of Organic Materials
Lithium Photo	Cameras	Metallic Lithium + Manganese Dioxide/ Carbon Monoflouride	Mixture of Organic Materials
Silver Oxide (button cells)	Watches	Silver Oxide + Zinc	Potassium/ Sodium Hydroxide
Zinc Air	Hearing aids	Zinc + Oxygen	Potassium Hydroxide

	Battery Types	Common Usages	Electrodes	Electrolyte
Secondary	Rechargeable Alkaline	CD/MD/MP3 players, toys, camera, flash light, remote controls, solar lighting	Manganese Dioxide + Zinc	Potassium Hydroxide
	Nickel metal hydride (NiMH)	Digital cameras, remote controlled racing toy cars	Nickelic/Nickelous Hydroxide + Metallic rare earth alloys	Potassium Hydroxide
	Nickel Cadmium (NiCd)	Power Tools	Nickelic/NickelousHydroxide + Metallic Cadmium or Cadmium Hydroxide	Potassium Hydroxide
	Lithium (Li) ion	Notebook computers, PDAs, mobile phones, camcorders, digital cameras	Compounds containing Lithium ions + Carbon materials	Mixture of organic materials
	Lead Acid	Car starter battery, lift trucks, golf charts, marine, standby power	Lead or Lead compounds	Sulphuric acid

Zinc-carbon is the highest sold battery in India followed by alkaline and rechargeable cells (1%)². Again, AA batteries, out of all the sizes, has maximum sale across the dry cell market, with a share of 73.5 percent.

1.2 COMPOSITION OF BATTERIES: THE RESOURCES TO RECOVER, THEIR USEFULNESS AND IMPACTS

Batteries come with varied compositions- different metals and materials used in their manufacturing processes.

Zinc Carbon battery: They are often termed “Heavy Duty” or “General Purpose” on their labels. They contain zinc anode, manganese dioxide cathode, carbon rod in the form of graphite and carbon powder to allow the flow of electrons and ammonium chloride or zinc chloride as electrolytes. (Zinc carbon cell structure³)

Primary Alkaline: They are called alkaline batteries because they use the alkaline solution of potassium or sodium hydroxide electrolyte instead of the acidic ammonium chloride or zinc chloride used in zinc carbon batteries. Zinc and manganese dioxide are the electrodes.

2 Eveready. 2015. Recharged to glow. Initiative coverage, Sector: Consumer. MotilalOswal Group. Available at <http://www.motilaloswalgroup.com/AnalystVideo/Pdf/72703677Eveready-20151218-MOSL-IC-PG042.pdf>

3 <http://www.oocities.org/thaibrains99/battery/batttoday.htm>

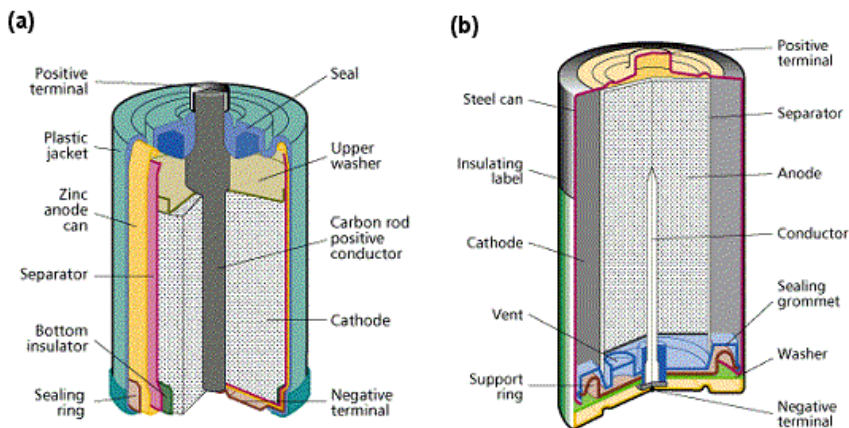


Figure 1: Zinc Carbon Cell Structure

Nickel plated steel case is used for the cylindrical container of both alkaline & Zn-C batteries. The capacity and shelf life of alkaline battery is higher than carbon zinc due to its electrolyte. The alkaline batteries were earlier used to contain mercury - a well-known toxic chemical – but it is now almost replaced everywhere. While mercury elimination from batteries came through a regulation in European Union, India does not have any law on mercury percentage in the batteries. Though the organised sector has shifted to zero mercury batteries, the batteries coming from the unorganised sector in India have no check of their mercury content and might be still using this toxic metal.

Nickel-cadmium Battery: They consist of a nickel (III) oxide- hydroxide $[\text{Ni}(\text{OH})_3]$ plate as the positive electrode (the cathode), a cadmium plate as the negative electrode (the anode) and an alkaline electrolyte usually of potassium hydroxide (KOH). They have a separator isolating the electrodes and all spirally rolled and enclosed in a casing using a metal, self-sealing plate. This design of nickel-cadmium battery allows more electrodes to be in contact with the electrolyte, thus lowering the internal resistance of the battery and increasing the maximum current that can be delivered.

Nickel-metal-hydride Battery: Unlike the nickel-cadmium battery a nickel-metal-hydride battery doesn't use any toxic metals. The electrode in this kind of a battery is made from a metal-hydride, typically an alloy of lanthanum, cerium, neodymium, praseodymium and other rare-earth elements, as well as a metal that is usually cobalt, nickel, manganese and/or aluminium. The metal-hydride anode is thus an inter-metallic compound.

Lithium-ion Battery: The lithium-ion battery is a recent entrant to the battery world and also among the fastest developing technologies. The positive electrode in a lithium-ion

cell is made of lithium-cobalt oxide (LiCoO₂) or lithium iron phosphate (LiFePO₄) in newer batteries. Negative electrode is a carbon rod. Lithium-ion is used in these batteries instead of lithium metal as lithium in metal form is highly unstable during battery discharge and recharge cycles and thus unsafe for conventional use. These batteries also often contain high-grade copper and aluminium depending on the active material along with the transition metals cobalt, nickel as well as rare earths. Primary lithium batteries contain lithium metal used in watches, sensors, hearing aids and memory backup. Lithium-ion batteries are also used in mobile phones and laptops. Lithium, as a metal, reacts violently in contact with moisture.

Silver oxide batteries: Used most frequently in watches, toys, and some medical devices, silver oxide batteries have silver oxide as cathode and zinc as anode with an alkaline electrolyte, usually sodium hydroxide or potassium hydroxide. The spent batteries have silver reduced from Ag(I) to Ag and zinc oxidised from Zn to Zn(II). They contain a small amount of mercury also. Most jurisdictions regulate their handling and disposal to reduce the discharge of mercury into the environment.

Table 2: Battery Composition by Type⁴

Type	Fe	Mn	Ni	Zn	Hg	Li	Ag	Cd	Co	Al	Pb	Other	KOH	Paper	Plastic	Alkali	C	Acids	Water	Other
Alkaline	24.8	22.3	0.5	14.9								1.3		1	2.2	5.4	3.7		10.1	14
Zinc-carbon	16.8	15		19.4							0.1	0.8		0.7	4	6	9.2		12.3	15.2
Lithium	50	19	1			2									7		2			19
Mercury-oxide	37	1	1	14	31								2		3		1		3	7
Zinc-air	42			35	1										4	4	1		10	3
Lithium	60	18	1			3									3		2			13
Alkaline	37	23	1	11	0.6										6	2	2		6	14
Silver oxide	42	2	2	9	0.4		31					4			2	1	0.5		2	4
Nickel-cadmium	35		22					15							10	2			5	11
NiMH	20	1	35	1					4			10			9	4			8	8
Li-ion	22					3			18	5		11					13			28

Note: All figures are in percentages

⁴ Battery Composition by Type. Available at https://en.wikipedia.org/wiki/Battery_recycling Accessed on 12.04.18.

BURDEN AND RESOURCE

Batteries are identified as a problem material in the waste stream and their environmental impacts are linked to their chemistry. As mentioned above, dry-cell batteries come in a wide range of shapes, sizes and chemistries. This makes them more complex and expensive to sort and reprocess. Some of these chemicals are extremely toxic and can cause damage to humans and the environment.

Careless disposal of Ni-Cd batteries, for example, lead to the corrosion of its metallic cylinder in the landfill. Eventually, **cadmium dissolves and seeps into soil, water supply and the food system.** Removal of cadmium contamination from soil, ground or surface water is almost impossible and the health impacts are innumerable. Cadmium exposure leads to respiratory problems with increasing possibilities of lung cancer, birth defect, bone deformities, known nephrotoxic affecting kidney, associated with progressive renal tubular dysfunction, severe osteoporosis and osteomalacia, anemia and yellowing of teeth, etc.

Lithium batteries if crushed and exposed in landfills when dumped in a charged state could ignite a fire. Landfill fires can continue for years underground. Appropriate disposal of batteries with lithium content can save from this hazard.

But batteries come with a number of metals, rare elements and alloys which can be profitably extracted from the used and disposed of cells and reused as raw materials. This has actually proved to be profitable in many parts of the world (see section below). Recycling of Zn-C and alkaline batteries can recover reusable zinc and manganese and has been done in developed countries. This is of immense importance in India as this is the most used battery. With the growing production and use of lithium batteries, recycling these spent batteries is also of great importance particularly to regain cobalt, nickel, lithium, copper and aluminum. Silver oxide batteries can be recycled to recover the precious metals, like silver though in very small quantity, zinc and mercury.

Recycling benefits are varied as enumerated below:

- **Utility of Recovered Resources:** Steel, aluminum, copper and zinc are known to have most wide uses globally of all the metals⁵. Zinc, a non-ferrous metal, has a wide range of applications in iron and steel production, metallurgy, machinery, electrical and chemical industries. Zinc is also among the most essential trace elements in the human body. World zinc production has showed an annual increase of 2.64% from 2004 to 2014. India

5 IBEF (India Brand Equity Foundation). Metals: market & opportunities. Available at https://www.ibef.org/download/Metals_210708.pdf

though historically one of the very first producers of zinc and zinc smelting, lags behind in production of this metal, leading to importing zinc for even domestic consumption. Manganese is also a highly useful metal and can be found in aluminum cans, alloys (steel and Manganese steel), ceramic, etc. and can be used as a catalyst, rubber additive, fungicide, oxidising agent and fertilizer when coupled with other elements and chemicals. Steel is widely used in construction, appliances and cookwares. All these metals are non-renewable natural resources which can be potentially recycled many times and have a substantial commercial value. The metal industry in India is expected to expand in the coming years with the growing market demand and hence it becomes critical that we focus on resource recovery of these metals.

- **Waste Generation and Pollution:** In addition to reducing the mining requirement, recycling will reduce the loads of these materials from going to landfill and ultimately contaminating soil and water. For example, heavy metals are discharged during the processes as air particulates and finally lead to soil pollution affecting human health through biological concentration and the natural environment. Also, it can potentially save a large quantity of waste generated during primary production.

Zinc is processed through smelting which converts zinc ores into pure zinc. There are two methods of zinc smelting, hydrometallurgical and pyrometallurgical. Currently, 80 percent of the global zinc production is achieved through hydrometallurgical processes. Smelting not only consumes huge amounts of energy but also leads to several types of pollution. Smelting can emit up to 21,500 kg of sulphur dioxide (SO₂) per tonne of zinc⁶ of which almost 97 percent is recycled through the desulphurization plants. Yet smelting along with the power plants supplying energy for smelting, casting and re-melting processes cause acidification of air due to the enormous quantities of sulphur and nitrogen oxides emitted⁷.

Smelting reportedly can contribute up to 75 percent to the total environmental load⁸. Hence, decreasing the use of primary zinc can remarkably reduce the same by decreasing CO₂ and other gaseous emissions, consumption of energy, water and waste. Also, its contribution to particulates and various nitrogen and sulphur oxide emissions is two to five times higher than casting and recycling combined. The amount of global warming potential caused by worldwide zinc production was 0.04 Gt carbon dioxide (CO₂) in 2008⁹.

6 Zinc Casting and Recycling, Reginald B.H. Tan and Hsien H. Khoo, Dept. of Chemical and Environmental Engineering, National University of Singapore

7 <https://pdfs.semanticscholar.org/a617/047da854b6d80681a3ca96aeb59fe7a43b6c.pdf> Accessed on 12.04.18.

8 Tan R.B.H. and Khoo H.H. 2004. Zinc Casting and Recycling. LCA Case Study. *International Journal of Life Cycle Assessment*, 1-8. DOI: <http://dx.doi.org/10.1065/lca2004.08.172>.

9 Nuss P and Eckelman M. J. 2014. A Life Cycle Assessment of Metals: A Scientific Synthesis. <https://doi.org/10.1371/journal.pone.0101298>

- **Resource Consumption for Mining and Extraction:** Mining and processing of metals is a hugely energy consuming affair. Use of recycled zinc and copper can itself save up to 76 percent and 85 percent of the energy used in primary production respectively¹⁰.

The energy exorbitant zinc production consumes approximately 15 gigajoule (GJ) of energy per tonne – 80 percent of which is spent during electrolysis. Increased use of recycled metal can eliminate a large chunk of greenhouse gases generated by power plants. When 100% recycled zinc is used, the overall environmental load drops by 90%¹¹.

Table 3: Energy requirement & savings for primary & secondary (recycled) production in Terajoules (TJ/100,000t)¹²

Metal	Primary Production	Secondary production	Saving/100.000 tonnes
Zinc	2400	1800	600
Copper	1690	630	1060
Nickel	2064	186	1878
Aluminium	4700	240	4460

Table 4: Carbon footprint and savings expressed in kilotonnes of co2/100,000 Tonnes for primary & secondary production¹³

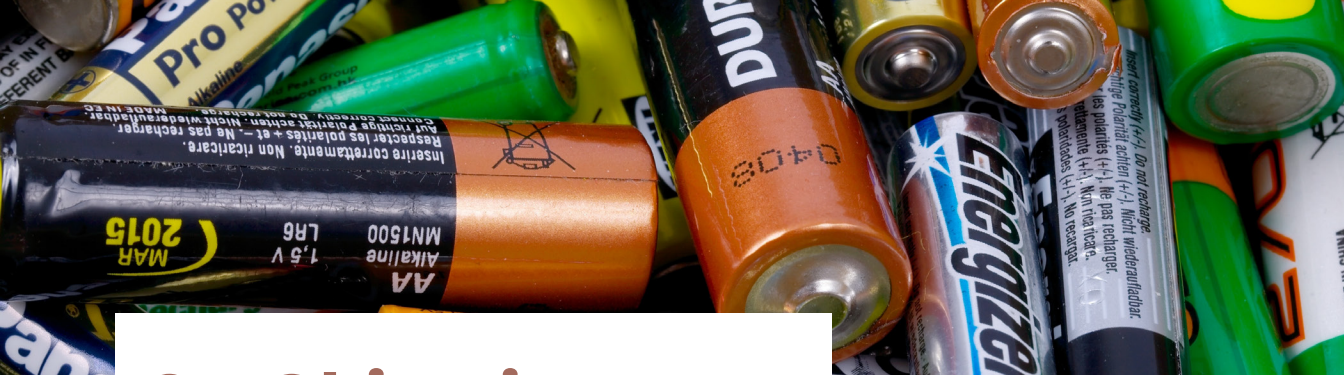
Metal	Primary Production	Secondary production	Saving/100.000 tonnes	Percentage savings of CO ₂
Zinc	236	56	180	76
Copper	125	44	81	65
Nickel	212	22	190	90
Aluminium	383	29	354	92

10 Hazra A.K. A brief perspective on the Indian metals recycling industry. FICCI (Federation of Indian Chamber of Commerce & Industry. Available at https://www.mrai.org.in/site/assets/files/5259/presentation_by_arnab_kumar_hazra_director_ficci.pdf Accessed on 13.04.2018.

11 Tan R. B.H. and Khoo H. H. 2004 Zinc Casting and Recycling. . LCA Case Study. *International Journal of Life Cycle Assessment*, 1-8. DOI: <http://dx.doi.org/10.1065/lca2004.08.172>

12 Bureau of International Recycling (BIR). 2008. Report on the environmental benefits of recycling. Available at http://www.mgg-recycling.com/wp-content/uploads/2013/06/BIR_CO2_report.pdf

13 Ibid



2. Objectives, Scope and Methodology

2.1. OBJECTIVES

The study aims to understand the status of household battery waste disposal and recycling scenario in India. The current study seeks to unravel the fate of these batteries from households till their disposal and evaluate their potential recovery.

2.2. SCOPE

- Understanding the disposal practices of commonly used batteries by the households, value chain of disposed batteries and the role of waste collectors, rag pickers, and recyclers in the entire chain of collection and dismantling of household batteries
- Identifying areas of battery recycling (excluding lead acid and button cell batteries) or dumping areas in Delhi NCR
- Understanding the recycling practices in the informal setup, material recovery and fate of non-recyclables
- Comprehending the economics and scale of recycling operations
- To estimate quantum of dry cells (mainly zinc-carbon) being dumped at landfill sites every year, resulting in resource wastage

2.3. METHODOLOGY

The study involved both primary and secondary research to get into the detail of household battery lifecycle. Following are the strategies adopted for the study:

1. Background research and analysis: Secondary research was carried out based on international and national studies, reports, research papers, reports from the national boards, ministries, battery manufacturing companies and the websites of formal battery recyclers around the world. The research included, a) Information on different types and compositions of household batteries, b) an assessment of their market share in India and the resource recovery potential, c) analysis of the existing policies and regulations of battery management, d) best practices of battery waste collection, disposal and recycling system in the country and across the world.
2. Primary study on the end-of-life household batteries: A primary research was conducted to trace down the entire supply chain process of these end-of-life household batteries (excluding lead acid and button cell batteries) to understand the collection, recycling and disposal practices in Delhi.
 - A household survey was carried out in 400 households of Delhi to understand the disposal practices of batteries used by the city households and the level of awareness regarding the same. The survey was conducted in North, South, East and West Delhi regions covering all the three income groups, viz., Low Income Group (LIG: 143 households), Medium Income Group (MIG: 114 households) and High Income Group (HIG: 143 households) for an inclusive and representative sampling.
 - Individual interviews and focused group discussions with the waste collectors, segregators, and dismantlers were conducted in four major hubs identified in and around Delhi, namely, Madanpur Khadar in South Delhi, SeemaPuri in East Delhi, Mundka in North West Delhi and Bhopura in Ghaziabad located in the bordering state of Uttar Pradesh marking the city's outskirts, to have an understanding of the flow-chain of household battery waste.
3. Resource wastage, yearly landfill load and the profit margin of the dismantlers were also calculated from the primary study.

2.4. LIMITATIONS

Small (household) batteries are very common in our everyday life, but their end-of-life management is mostly ignored by stakeholders including the regulatory bodies, producers and the consumers in India. The existing recycling operations are very insignificant in volume and entirely informal operating behind the eyes of the authorities and certainly not meeting any environmental criteria. Given this situation, conducting the primary study was challenging as the access was denied to such places in fear of getting caught and the interviewees were also not eager to disclose all the relevant details. Availability of information

for secondary research was also very limited owing to the lack of studies on the same. The major primary research limitations include: a) Area of the study is restricted to Delhi NCR, hence, gives a picture of urban India, b) Since only face- to- face interview measures were used, common-method variance and response consistency effects may have biased the observed relationships, c) Very few dismantlers could be interviewed as the operations are closed now and most of them have changed their professions which made it difficult to locate them, c) Non-availability of data regarding the actual volume of dry cells recycled in the whole of India.

Due to limitations of the study, button cell could not be included. But these tiny batteries can be problem products as historically they contained mercury. Though the organized sector has phased out the toxic metal, lot of button cell batteries in India are being manufacturing informally.



3. A Lowdown on Dry Cells in India

3.1. MARKET SIZE AND DEMAND

Global economic growth drives the market demand for consumer batteries as a result of the increased consumer incomes and higher demand for high-performance batteries and battery-enabled consumer devices. The global battery market for consumer products (primary and secondary batteries) is forecasted to exhibit steady growth during 2017 to 2021, with an expected reach of \$55.4 billion by the end of 2017^{14,15}. A market research group, The Freedonia Group, forecasted an annual growth of 7.7 percent of the world demand for primary and secondary batteries amounting to US\$120 billion in 2019.

Indian market is still dominated by non-rechargeable batteries, mainly because of price sensitivity.

The real growth, globally, lies in secondary (rechargeable) batteries accounting for 76.4 percent of the global market.¹⁶ Growing use of high-drain electronic and electrical devices would drive a strong growth for primary batteries globally, but the secondary battery like lithium-ion rechargeable batteries would display maximum growth opportunities in the world owing to the rising popularity of consumer electronic devices, including mobile phones. The market for lithium ion batteries is the fastest growing and expected to go beyond US\$30 billion by 2020.¹⁷

14 Global Information, Inc. Market research report: Global battery market for consumer products 2017-2021. Available at: <https://www.giiresearch.com/report/inf565827-global-battery-market-consumer-products.html> Accessed on 13.04.18.

15 Markets and Markets. Available at <https://www.marketsandmarkets.com/PressReleases/automotive-battery.asp> Accessed on 02.05.18.

16 Global Battery Markets. Available at http://batteryuniversity.com/learn/article/global_battery_markets Accessed on 02.05.18.

17 Global market for Lithium-ion batteries – forecast, trends & opportunities 2014-2020. Available at <https://www.marketresearch.com/product/sample-8323376.pdf>

In India, the total battery market is projected to be valued at 8.6 billion USD by 2022¹⁸. According to a report by one of India's leading dry cell manufacturers, the dry cell battery (primary and secondary batteries) market volume in the country was 2.7 billion amounting to INR 16 billion in the year 2016-17.¹⁹

Contrasting to the World scenario, India's battery market is still dominated by zinc-carbon cells which are non-rechargeable, with a share of 97 percent. The remaining 3 percent constitutes of alkaline battery and rechargeable battery segments, accounting for the balance 2 percent and 1 percent of the market share respectively²⁰. Thus, despite being present for over 15 years, rechargeable batteries are nowhere close to the Zn-C batteries mainly due to the price-sensitive nature of the Indian consumer. The sale of AA batteries across the dry cell market, in India is the maximum with a share of 73.5 percent.

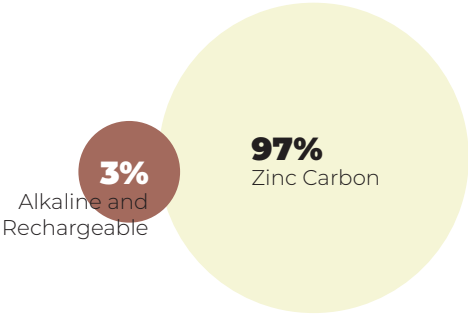


Figure 2: Distribution of Dry Cell Market in India

Table 5: Distribution of Dry Cells among its various types in India²¹

Battery Category	2015-16 (%)	2014-15 (%)
D	10.6	13.0
C	0.3	0.2
AA	73.5	73.6
AAA	15.6	13.2
Total	100.0	100.0

Indian dry cell market is dominated by a few brands. Eveready Industries India Limited (EIL) has a major share of 50 percent between its two subsidiaries, Eveready and Powercell. Nippo, Panasonic, Duracell and Geep are the other major players in India in this category.

18 Research and Markets.https://www.researchandmarkets.com/research/97ns8n/india_battery Accessed on 02.05.2018.

19 Eveready Industries India Ltd. 2017. Powering Up. Annual Report 2016-17 <http://www.evereadyindia.com/investor-relations/annual-report-16-17.pdf>

20 Eveready Industries India. 2016. Annual Report 2015-16. Available at www.evereadyindia.com/investor-relations/annual-report-16-17.pdf

21 Eveready Annual Report., 2015-16. Available at www.evereadyindia.com/investor-relations/annual-report-16-17.pdf

3.2. CURRENT USAGE & DISPOSAL PRACTICES

As stated in the earlier sections, batteries are used quite widely in variety of equipment or gadgets. Multi- purpose utility of these small batteries means that they are useful not only in households but also in offices or commercial spaces. A look into the current usage and disposal practices from households, during the scope of the primary study, brings to light the fate of the used batteries in Delhi. The situation might be similar in other parts of the country as well as the battery usage is not really very city- specific.

Usage: According to the survey conducted in Delhi households, battery usage is highest in remote controls (television, air conditioner etc.) and clocks. About 99 percent of the households were found to be using batteries for these two gadgets. Use of batteries in toys, torches and camera is also quite common. Use of battery operated electronic gadgets was observed to be more in the households belonging to HIG, indicating a pattern of increased consumption of batteries with rising income.

Though the survey was limited to Delhi, secondary research does point out that the usage is similar across the country. Also, though for remote controls mostly primary batteries are used, in toys or cameras, rechargeable batteries are also used.

Waste generation: Lifespan of batteries may differ depending on the usage as well as quality, but all of it ends up as waste eventually. In tune with the usage patterns, the highest number of batteries was found to be disposed by the HIG category (41%) followed by MIG (36.6%) and LIG (22.4%).

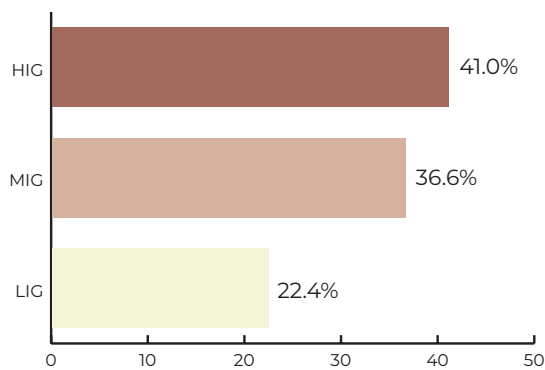


Figure 3: Batteries disposal by households (income groups) in Delhi

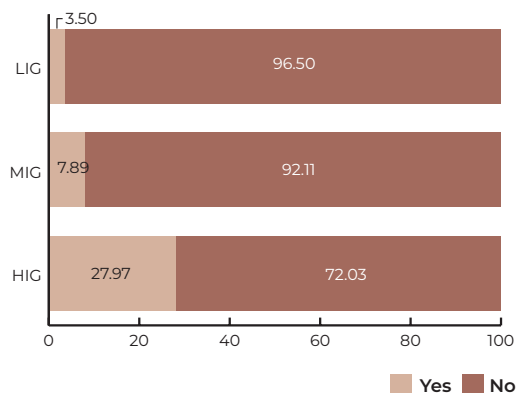


Figure 4: Awareness levels among the households in Delhi (%)

Awareness on the hazards associated with batteries: Batteries generated at the household level are categorized as hazardous domestic waste under the Solid Waste Management Rules in India and are supposed to be segregated at source. However, a key factor behind all waste source segregation is the awareness level of the users about the risks associated with the materials. The survey shows that 86.5 percent of the respondent households were unaware of the hazards associated with batteries. The awareness level also varied with the economic status; with HIG households being the most aware at around 28% and LIGs being the least aware at 3.5%.

DISPOSAL PRACTICES BY HOUSEHOLDS:

The disposal practices of households, as reported by the survey, sadly are nowhere close to the recommended practice (segregate as household hazardous waste). Most of the households surveyed, that is, 92.5% were found to throw the batteries in the common household dustbins after use. Very few mentioned about selling the batteries (6.25%) or storing (1.25 %). Small number of households indicated that they sell it to the *kabadiwallas* (small scrap dealers) at a rate of Rs. 4-5 per kg. But it was quite clear from the household survey that majority of the batteries end up in normal municipal waste bins.

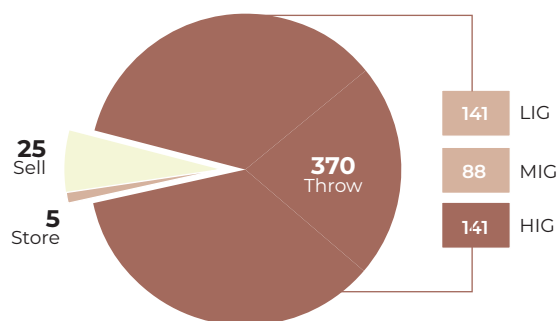


Figure 5: Battery Disposal practices by households in Delhi (in numbers)

Lack of proper management system for the batteries used in households is a matter of grave concern for the country. These are wastes categorized as household hazardous, yet neither this is informed to the citizens, nor are they instructed for its separate disposal. Currently there is no separate collection and recycling facility.

3.3. VALUE CHAIN OF SPENT BATTERIES

In India, in the absence of any formal structure for small battery management, the value chain mainly includes informal players. From the point of discarding of the batteries at the generation point, various stakeholders, like waste pickers, rag pickers, *kabadiwalas* (*kabadis* are a group of people informally collecting junk or scrap), and dismantlers are involved at various stages for their commercial value. The figure below shows the value chain of battery waste management in Delhi in the informal sector.

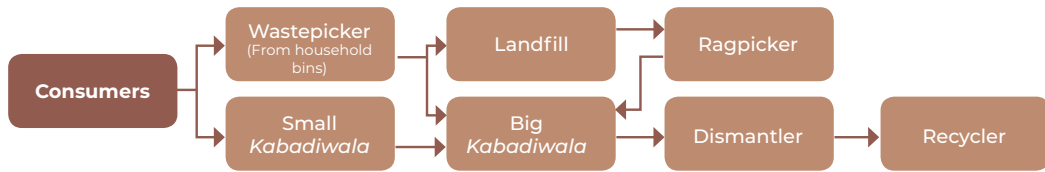


Figure 6: Waste flow for Battery waste in Delhi

While tracking down the routes, the current study reveals the existence of an informal chain for small battery waste, though this set up is largely abandoned now. The players in the value chain are:

- **Waste Picker:** Collects waste from door to door. Could be part of the formal municipal/ local body waste management system or private agency hired to provide waste management in the locality.
- **Small Kabadiwala:** Informal waste collectors who buy recyclable and/or reusable waste materials (e.g., metals, glass, plastic, etc.) from door to door.
- **Landfill:** The site for disposal or dumping of waste.
- **Big Kabadiwala:** Informal waste collector who collects large amounts of recyclable and/ or reusable waste materials from small kabadiwalas, waste pickers, rag pickers, etc. They generally have a ware- house for storage and segregation of waste.
- **Rag Pickers:** Individuals who rummage through landfills to collect recyclable and/or reusable waste materials.
- **Recyclers:** Informal (in case of small batteries) groups who depending on the nature of the waste, dismantle, recover or smelt valuable resources from waste.

3.3.1 THE INFORMAL SECTOR: ROLES & THE STATUS

As mentioned in the earlier sections, commonly used small batteries vary in their types and chemistries. Depending on their chemical composition, their recycling processes also differ. A probe inside Delhi's informal battery waste recycling units during the current study reveals the collection, dismantling and recovery scenario as well as the situation of the units.

Zinc carbon batteries were the most commonly recycled ones as they are also consumed in the largest quantity. Zinc anode, carbon rod and manganese dioxide-carbon mixture of the cathode (Called “carbon powder” by local dismantlers) and steel casings are recovered from

these cells in the recycling units. Following is an account of the chain of systems prevailing in the informal small battery disposal and recycling set up as came out during the primary study.

3.4. COLLECTION & DISMANTLING SCENARIO IN DELHI

The consumer or households, usually discard the batteries in the household waste bin. In the most common practice, along with other household wastes, the used batteries are also picked up by the waste pickers and taken to the community bins (or dhalaos). At this stage, either the batteries, along with other valuable resources, are segregated by the waste pickers and sold further or are taken along with other waste and dumped at the landfill. The households also sometime choose to store the batteries and sell it directly to small kabadiwallas.

Along with other wastes the ragpickers pick up the discarded batteries, if they can sell it further. Waste pickers, rag pickers and small kabadis sell the collected batteries, mixed with waste glass or scrap metals, to the big kabadiwalas at a rate of Rs. 1-1.5 per kg. Big kabadis act as an important junction for collection of used small batteries and further send them to the recyclers. Intact and segregated batteries go from the big kabadis to the dismantlers/recyclers at a rate of Rs. 2.5-3 per kg depending on the price of zinc in the market. Though some amount of batteries waste gets picked up, a huge portion of discarded batteries remain in the landfills, as it is difficult to pick it up from the pile and also the economics are not very lucrative. Currently the battery dismantlers have heaps of batteries stored which they've not been able to sell because recycling in and around Delhi has stalled for a number of uncertainties (See section 3.2.2.c).

During the course of primary study interactions, it came to light that approximately a decade ago, the city witnessed a proliferation of informal recycling centres for the household batteries but the collection and dismantling of batteries was, even then, carried out in select places, mainly because it was not very profitable. Madanpur Khadar, Seemapuri, Mundka, Bhopura are some of the hotspots in NCR where these operations were carried out. Out of these, Seemapuri was considered to be the largest and the main hub of used household battery dismantling. Rest of the areas acted as collection centres. There were mainly 5 recyclers involved in dismantling and melting of metals in Seemapuri. About 50 big kabadis were present in the other areas that collected and segregated waste informally. The primary study also reveals that a big kabadiwala could collect a total of approximately 0.5-0.6 tonnes of used batteries daily from different parts of Delhi. So these big kabadis spread across Delhi would collect approximately around 25 tonnes of batteries every day. These were then sold to the recyclers of Seemapuri for processing.

Toxics Link team visited Seemapuri to understand the processes and business in these dismantling units but operations had been shut for over a year. A look at the non-functional units revealed that these were small houses or rooms attached to the residential houses. They looked dingy and lacked proper ventilation. Remains of cathode material in powdered form and bags full of discarded batteries spread all over the place along with other household hazardous waste were observed in these units. It did not appear that any pollution control facilities or health safety measures were deployed in the units.

The local sources revealed that all types of used small batteries were dismantled here into their components of anodes, cathodes, steel casings, etc. The same sources added that on an average, 5-10 part time labourers used to work in these dismantling units. All workers were female and came from neighbouring slum units. The untrained labourers were hired on the basis of the scrap volumes received and the wage rate was between INR 120 to INR 150 per day for this hazardous work. Their job was to separate the battery components using hammer, pliers and pins and recover useful resources from these. They worked with bare hands without using gloves or masks during the entire process, thus, with primary exposure to the toxic inhalations, ingestion and dermal absorption (also observed during earlier visits by our team couple of years back). After dismantling the segregated parts were sent either to melting centres or scrap markets directly depending on the types of recovered materials.

In the waste battery parts, metal anode, steel casing, carbon rod and the mixed powder of manganese dioxide and carbon were mainly separated. The metal components separated from the anode were transferred to melting centres for further recycling. Generally, the dismantlers in Seemapuri had their own melting units for processing the recovered zinc. There are melting centres situated in the neighbouring states also, like Meerut in Uttar Pradesh and Baddi in Himachal Pradesh. The steel casing which is tin-plated and top of the waste batteries goes to the scrap market at the value of tin.

RESOURCES RECOVERY

According to some of the units visited earlier during the study, the informal process (dismantling & smelting) generally recovers 30 to 50 kg of pure zinc depending on the size and quality of batteries (varies for local and branded batteries), 25 to 30 kg of carbon rods, 50 to 60 kg of tin-plated steel casing and 400 to 500 kg of manganese dioxide and carbon powder from a tonne of used batteries.

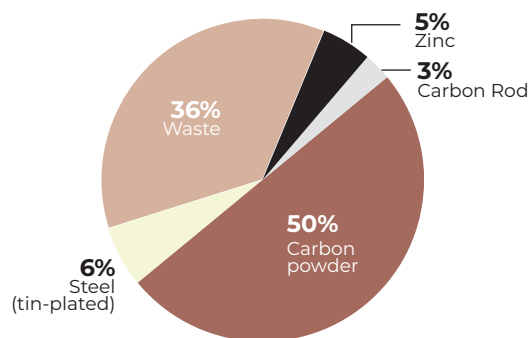


Figure 7: Resource Recovery (%) in informal battery recycling

The battery casings and tops containing steel are easily recoverable and saleable in the scrap market. The recycled zinc is melted to purify and be sold as zinc slabs for further use generally at a rate 20 percent less than the market rate of zinc. Carbon rods can be used in making motors of electronic appliances, like, fans, sewing machines or in mixer grinders. They are also used by wet cell manufacturing units. The black powder of manganese dioxide and carbon is used as a heat absorbent in the informal melting units of aluminium, lead or zinc purification. The unsold black powders were sometimes thrown away in open without giving a thought to the hazardous content. The rest including the plastic jacket, separator, insulator, sealing ring and washer within the batteries are treated as waste and are dumped illegally in nearby open areas of Bhopura in Delhi-Uttar Pradesh border or buried underground.



Figure 8: Stages of Battery Dismantling

- 1, 2: Peeling off of the battery casing
- 3,4: Taking out the carbon rod and MnO₂-carbon powder
- 5: Exposure during dismantling
- 6: Resources recovered after battery dismantling

In an attempt to authenticate the findings of resource recovery from informally dismantling a battery, battery dismantling was carried out by the primary research team at Toxics Link. Zinc was found to be thinly lined on a cardboard layer. Recovery of pure zinc would need high quality processing. Amount and quality of the recovery would depend on the process applied. This probably contributes to an inefficient recovery in the informal process.

FATEFUL END OF WHAT COULD HAVE BEEN A SUSTAINABLE VENTURE

Delhi's battery dismantling units along with the few smelting chambers were in operation for more than a decade. But they were shut down sometime during 2016 owing to a number of rising challenges. These small scale units were operating in these fringe areas of the city without proper infrastructure for dismantling, smelting or required health-safety measures for their employees. With the rising population, the city boundaries have been expanding and even the fringe areas have been becoming more expensive, making some of these areas unviable for such operations. Also these areas are more under the scanner of regulator agencies and hence it is becoming increasingly difficult for units to carry out their operations as visible hazardous emissions and effluents from them raise objections from neighbours. Unavailability of labour was another challenge. Health impacts of the hazardous dismantling process were becoming prominent among the labourers leading to a loss of the experienced labourers and demand for increased labour charge. This resulted into shrinking of the operation, inefficient recovery and thereby lowering profit margin. With the recycling getting halted, the whole chain of informal battery recycling came to an end in the city. During the Toxics Link team inspection, none of the *kabadiwalas* were found to accept spent small batteries. *"Masala batteries (as is called commonly in the circle) are of no use these days. We don't buy them and even if we get batteries along with other waste we send them off to the landfill with other non-recyclables,"* shared an employee of a big *kabadiwalas* unit. However, very few waste collectors at a small level still segregate and store the dry cell batteries in the hope of getting sold in future. This study does not conclude an end of the battery recycling across the country, in fact, informal recycling in the neighbouring states might still be existing which could include some of Delhi's spent dry cell batteries.

WHY THE INFORMAL BATTERY DISMANTLING UNITS SHUT DOWN IN DELHI

Shyam (name changed) was a recycler from the fringe of the national capital city. His dismantling unit and smelting chamber is closed now. Sitting in the abandoned site he recollects his story to the Toxics Link representative about the gradual shutting down of a business he had been working in for the past 20 years. Years back he had learnt this skill from a Bangladeshi resettler. He had 30-35 female workers in his unit initially. The workforce mainly included a family with the mother and all her daughters mostly of a very young age. Inflow of used batteries was good, ensuring steady income for Shyam. He used to receive almost 20 tonnes of zinc carbon batteries every month from big kabadiwalas in Delhi. He also got other kinds of batteries in smaller quantities. His team of ladies used to separate zinc anodes, tin plated steel casing, carbon rods and carbon powder (manganese dioxide and carbon mixture used as cathode) from these cells. When the units were in operation, these ladies were paid in the range of INR 120 to INR 150 per day.

But then came a time when the locality started getting crowded and it was becoming difficult to manage the activities in residential areas. "The smelting units used to generate white smoke. Now that was a problem in the changing city- scape. The abandoned lands where the waste used to be dumped were also getting occupied. Landfill was far away and sending the daily waste would have been too expensive. Moreover, objections from neighbours for the polluting dismantling activities were also a headache," describes Shyam. His labourers also started waking up to the pernicious health hazards associated with this job. Peeling off batteries day after day, some of which exploded, started taking a toll on their health. Initially, they protested against dismantling other primary cells and rechargeable cells which they felt were more harmful. But they continued to dismantle zinc carbon cells, without taking safety precautions, thinking that it was safe to separate the components of this type of battery. But slowly they discovered that dismantling these cells too was affecting their health. Then they started asking for higher wages (INR 250 to INR 300 per day) which he (Shyam) refused to pay as it would have led to a lowering of profit for him. Slowly, the employees who were experienced started slipping away and only a few of around 10-12 were left. The experience was important as there can be nickel, lithium or even small lead acid batteries (made by local companies) which could lead to even life threatening accidents if attempted to dismantle with bare hands.

Fear of getting caught for carrying out illegal activities in such a crowded place was also at the back of his mind. Shifting outside Delhi was an option but for him leaving his settlements and family and to start again was not feasible. Finally during October 2016 he had to shut the operations much like the other recyclers in his area. Demands for the recovered zinc and carbon rods were also going down with closure of informal zinc melting factories at Mandoli in eastern Delhi border and grinder making factories in Meerut. Now, most of the big kabadiwalas and dismantlers like Shyam are left with heaps of batteries lying in their warehouses but without any buyers to sell them to.

3.5. ECONOMICS OF INFORMAL BATTERY RECYCLING

Small battery recycling must be both environmentally beneficial and economically feasible in order to be widely implemented. Recovering valuable end products can recoup some of the costs of battery recycling which apart from the manpower, establishment cost and technical investment also include environmental and health safety measures. However, informal battery recycling units neither apply high performance treatment process nor do they pay any heed to environment or health concerns.

A summary of the monetary value attracted by these discarded used batteries in the informal battery recycling value chain or industry in Delhi is as follows (at the time of their operation in 2016).

Table 6: Economics

Seller	Buyer	Product	Price (INR per kg)
Households, Waste Pickers, Rag Pickers, Small <i>Kabadis</i>	Big <i>Kabadis</i>	Used battery along with other household waste	1-1.5
Big <i>Kabadis</i>	Recyclers	Segregated discarded batteries (depends on the price of zinc in the market)	2.5-3
Recycler	Scrap market	Steel (tin-plated) contents recovered from discarded batteries	5-6
Recyclers	Industry	Carbon rods recovered from discarded batteries	10
Recyclers	Industry	Zinc recovered & smelted from discarded batteries (20% less than the market price)	120

Profit Margin of the Dismantler Interviewed in Seemapuri (before they shut down)

Monthly Input Cost for Material, Operation & Maintenance

Average volume of used battery waste received per month	20 Tonnes or 20000 kg
Cost price of the waste battery per month [@ INR 3 per kg of waste]	INR 3 x 20000 = INR 60000

Labour charges per month [12 labours, @ INR 130 per person per day for 25 working days]	INR 39000
Monthly Cost for dumping the waste generated after recovery	INR 1500
Recovery per Tonne	
Zinc recovered post smelting per ton of battery received (average)	40 Kg
Graphite rod recovered per ton of battery received (average)	27 kg
Carbon Powder recovered per ton of battery received (average)	450 kg
Steel (tin-plated) recovered per ton of battery received (average)	55 kg
Recovery per month	
Total Zinc recovered per month	1100 kg
Total amount of Graphite Rods recovered per month	540 kg
Total amount of Carbon Powder recovered per month	9000 kg
Total amount of Steel (tin-plated) recovered per month	1100 kg
Recovery Revenue	
Selling Price (S.P) of the Zinc recovered per month [@ INR 120 per kg]	INR 132000
Selling Price of the Graphite Rods recovered per month [@ INR 10 per kg]	INR 5400
Selling Price of the Carbon Powder recovered per month [@ INR 2.5 per kg]	INR 22500
Selling Price of the Steel (tin-plated) recovered per month [@ INR 7 per kg]	INR 7700
Gross Revenue per month	INR 167600
Total expenses incurred per month	INR 88020
Monthly Net Profit	INR 67580

Continuing the operations with an increased labour charge from INR 130 to INR 250 would have reduced the monthly profit to INR 31000 at the same rate of zinc but in the meantime the zinc price has also increased by 35 percent.

RESOURCE RECOVERY

Zinc Carbon cells are the majority dry cells in the Indian market. Hence, the share of AA, AAA, D and C cell types in the dry cell market would also majorly apply to the zinc carbon cells in India. Following is an estimation of the resources that can be recovered from zinc-carbon cells consumed in India during the year 2015-16:

Types of Batteries	Market Share in 2015-16 (%) ²²	Pieces of batteries consumed in the year*	Weight of the spent cell (g) ²³	Total weight of batteries consumed (Tonnes)	Percentage of recoverable resources per cell ²⁴			Total weight of recoverable resources from the batteries consumed in 2015-16 (Tonnes)*		
					Zinc	Mn	Steel	Zinc	Mn	Steel
D	10.6	286200000	91.69	26242.25	18.29	26.62	14.03	4799.71	6985.69	3681.79
C	0.3	8100000	48.53	393.09	31.13	18.86	17.50	122.37	74.14	68.79
AA	73.5	1984500000	17.70	35125.65	25.78	21.70	19.97	9055.39	7622.27	7014.59
AAA	15.6	421200000	7.22	3041.06	34.46	18.94	2.74	1047.95	575.98	83.33
		2700000000						15025.42	15258.07	10848.50

**Calculated against the total consumption of Zn-C batteries in India in 2015 (2.7 billion pieces) assuming 100 percent of the given battery types in India are of Zn-C which is largely the case in the country.*

This shows the possibility of recovery of 15 thousand tonnes of zinc and manganese each and about 10 thousand tonnes of steel in the year 2015-16. This amount equals to an average resource recovery of 60 percent by weight of the total batteries consumed across the types. In addition to the metals, carbon or graphite rods are also recoverable and reusable. The number of recoverable Carbon would be as many as the number of ZnC cells in the market. Formalisation of small battery recycling can avert the environmental impacts associated with mining of these limited natural resources (land degradation, waste and energy use), b) energy and water consumption during the process of their extraction and purification, c) landfill loads and space and d) soil and water environment due to the hazardous land-filling.

²² Eveready Industries India Ltd. 2016. Annual Report 2015-16.

Available at www.evereadyindia.com/investor-relations/pdf/annual-report-15-16.pdf Accessed on 03.05.18.

²³ MajharulHaque Khan and A.S.W Kurny. 2012. Characterization of Spent Household Zinc-Carbon Dry Cell Batteries in the Process of Recovery of Value Metals. Journal of Minerals & Materials Characterization & Engineering, 11 (6);641-651

²⁴ Ibid

Table 7: Formal- Informal comparison

Materials Recoverable in one ton of AA batteries: a comparison of formal & informal ways			
Formal		Informal	
Materials Recovered	Recovery in kgs	Materials Recovered	Recovery in kgs
Zinc	258	Zinc	50
Steel	200	Steel	60
Manganese	217	Manganese	0
Remaining (carbon powder etc.)	326	Carbon powder & rod	530

Traditional formal battery recycling processes are either hydrometallurgical or pyro metallurgical. The process involves mechanical pre-treatment, chemical based steps to create high-purity end products and thereby, the cost of both the materials and high energy consumption. Thus, the cost of resource recovery in many cases, particularly for the metals, like, zinc, manganese, iron drives up and makes it economically less profitable. For example, according to estimation by Battery University, the cost to recycle alkaline batteries is higher than the value of the end products of recycling²⁵. Therefore, sustaining small battery recycling without supplemental funding or adding surcharges to battery prices might be challenging. Viable and sustainable recycling needs reduction in recycling cost.

Recycling lithium-ion batteries has safety issues from electrical dangers, chemical hazards, burning risks, water sensitivity of lithium hexafluorophosphate (possible electrolyte) and other potential reactions. Hence, a process chain combining of several unit operations is supposed to be carried out to recover the valuable materials. The processes include deactivation or discharging of the battery, disassembly of battery systems, mechanical processes, hydrometallurgical processes and pyro metallurgical processes. The process of lithium extraction from spent batteries is not generally commercially viable as it is way more expensive than mining lithium. But efforts are being made now to commercialise the industry as the demand of such batteries is going high. Sony and *Sumitomo Metal* in Japan and Umicore in Belgium have developed technology to retrieve cobalt and other precious metals from spent lithium ion batteries.

²⁵ I. Buchmann, "Battery University: How to Recycle Batteries," Cadex Electronics, 2010.

3.6. LANDFILL LOAD OF DRY CELLS IN THE ABSENCE OF RECYCLING

1. **Battery Consumption and Landfill Load of Dry Cells in India:** Recycling of dry cells is informal and almost negligible in India. In the absence of any formal small battery management system in the country or when not taken back by the producers, the waste from batteries end up in landfills, and the landfill load of household battery waste can be considered almost at par with the consumption amounts. There are no studies available on the amount of battery waste generated in India or even the percentage composition of battery waste in the household solid waste. However, a rough estimation can be made on their dumping load from the consumption amount of dry cell batteries.

Dry cell battery consumption in India is 2.7 billion pieces (2016-17) of which 97 percent, that is, around 2.6 billion pieces are zinc-carbon cells. Reports say 40 percent of the Zn-C cells in use are TV remotes, 25 percent are in flashlights, 25 percent in clocks or watches and 10 percent in toys, AC remote, cameras, etc.²⁶. Battery lives of dry cell batteries are short, more so with increased energy requirement. An estimation of their shelf lives through market survey reveals variation between the types depending on the rate of use. While TV remote batteries last for 8 – 9 months, flashlight batteries stay for 10 – 12 months and watch, camera, AC remote, toys are mostly used for more than a year. This suggests **that close to 90 percent of the annual zinc-carbon cell consumption eventually goes to landfills every year in India and the number amounts to about 2.4 billion pieces**. Rest of the dry cell batteries, that is, alkaline and rechargeable ones have higher shelf lives, ranging above 4 years. They also eventually add up to the volume of battery landfilling.

3.7. IMPACT OF BATTERY LAND-FILLING

Small dry batteries contain different kinds of heavy metals of different concentrations. Heavy metals are toxic and bring hazard to health and environment.²⁷ From the household trash, batteries reach landfills where the casing will corrode over time and chemicals will leach into the soil. Depending on the chemical nature of the heavy metal contents and geo-climatic conditions the degree of leaching will vary.²⁸ Consequences are many including,

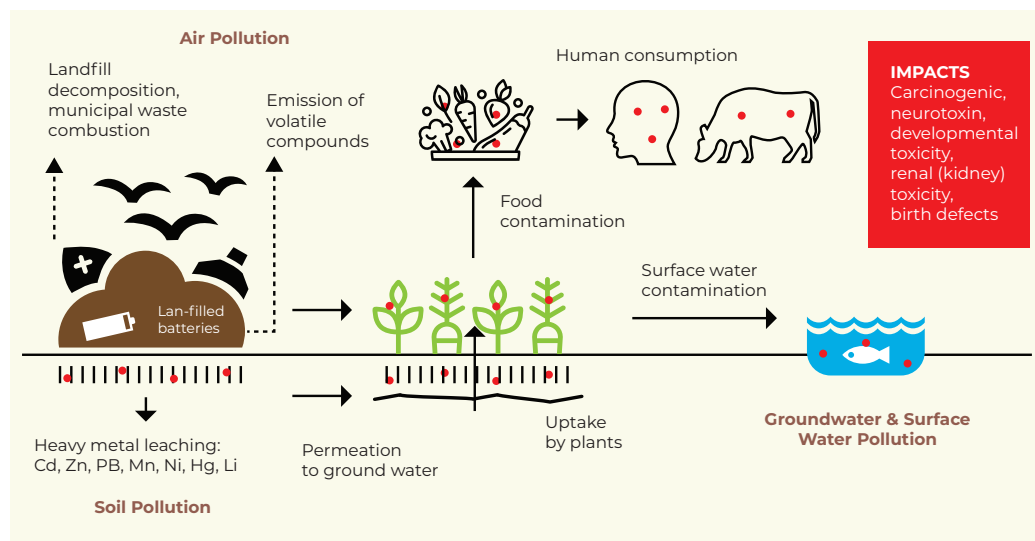
26 Eveready. 2015. Recharged to Glow, 2015. Eveready Report by MotilalOswal. Available at <http://www.motilaloswal.com/site/reports/HTML/635862860567528227/index.htm>. Accessed on 12.04.18

27 Panero S., Romoli C., Achilli M., Cardarelli E., Scrosati B. 1995. Impact of Household batteries in landfills. *Journal of Power Sources*, 57(1-2): 9-12. DOI [https://doi.org/10.1016/0378-7753\(95\)02230-9](https://doi.org/10.1016/0378-7753(95)02230-9)

28 Commission of the European Communities. 2003. Directive of the European Parliament and of The Council on Batteries and Accumulators and Spent Batteries and Accumulators: Extended Impact Assessment. Commission Staff Working Paper. Available at http://ec.europa.eu/environment/waste/batteries/pdf/exten_impact_assessment.pdf accessed on 25.05.2018.

a) permeation of the harmful contents of batteries into the soil, groundwater and surface water, b) release of toxins into the air with municipal waste combustion, c) heavy metal uptake by plants and thereby accumulation in fruits and vegetables, d) human and animal consumption through food and water.²⁹ The metals associated with batteries can cause neurological impacts, kidney damage, birth defects, and cancer.³⁰

ROUTES OF BATTERY WASTE POLLUTION



In an assessment of economic and environmental impacts of Extended Producer Responsibility Programme for battery recycling in British Columbia, it has been found that take back of batteries contribute to, a) avoiding collection & processing cost, landfill sitting, development, management and post-closure cost, b) earn end-market recovered material value, c) landfill space savings, d) reduction in greenhouse gas (GHG) emissions, d) energy savings from reduced need for extraction/processing of virgin materials for products and avoided landfilling.³¹

29 Malavika C.R. 2004. Environmental Effects Associated with Battery Disposal. Available at <http://www.frost.com/sublib/display-market-insight-top.do?id=20759887> accessed on 24.05.2018.

30 Dillon C. 1994. The ecological impact of batteries. Available at <http://repository.cmu.edu/cgi/viewcontent.cgi?article=1216&context=ece> accessed on 24.05.2018.

31 Fichtner K., Bartlett V., Seidel C., Gies G., Walker M. 2014. Assessment of Economic and Environmental Impacts of Extended Producer Responsibility Programs in BC. Report by Morrison Hershfield. Available at <http://www.metrovancouver.org/services/solid-waste/SolidWastePublications/AssesmentEconEnvImpactsEPRPrograms-Feb2014.pdf> accessed on 25.05.2018.

3.8. END-OF-LIFE BATTERY MANAGEMENT REGULATIONS IN INDIA

Efficient waste management is a global concern and a major challenge to achieve sustainable development. Due to the rising amount of this waste and their consecutive environmental impacts, regulations have been framed for battery waste management in different parts of the world, particularly in the developed countries. Battery waste management approaches have majorly been Extended Producer Responsibility (EPR) in the developed nations including the European Union. But in most places local government has been also assigned responsibility to, i) inform and make the community aware, ii) have separate collection facility, and iii) recycling.

India has several waste regulations yet the several layers of battery management have never been properly addressed. In the battery waste segment, India has guidelines for the disposal of lead acid batteries. In the Batteries (Management and Handling) Rules, 2001 and the subsequent 2010 amendment by the Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India provides a set of regulations for handling of lead acid batteries (MoEF, 2001). Under these rules, a Deposit Refund System (DRS) is in place for recycling of lead acid batteries in the market. Used Lead Acid Batteries (ULABs) procured by retailers are to be sold only to registered (formal) recyclers, who in turn are mandated to use environment friendly processes to recycle the lead. In addition, manufacturers and importers are also required to be part of the buy-back system. But this is not applicable to small batteries being discussed in this report.

Small batteries are not regulated separately in India but do find mention under the Solid Waste Management Rules, 2016 (SWM). It has defined 'used batteries' as 'domestic hazardous waste' along with paint and pesticide containers, CFL lights, expired medicines, broken mercury thermometers and used bio-medical waste generated at the household level. Source segregation of domestic hazardous waste is mandated under this rule. Though EPR is introduced in the rule it is defined as only the responsibility for producers of packaging products such as plastic, tin, glass and corrugated boxes, sanitary napkins, etc. and not for the small batteries.

Following are the provisions for domestic hazardous waste under the rule:

- Segregated storage and handing over of such domestic hazardous waste by the waste generators
- Setting up of waste deposition centres for safe disposal of domestic hazardous waste by waste generators in cities or towns as, a) one per twenty square kilometre area, b) with

deposit directions for waste generators, c) center timing notifications for receiving the waste.

- Safe storage and transport to hazardous waste disposal facility
- Public awareness on domestic hazardous waste segregation at source
- Management of the hazardous waste in accordance with the Hazardous Waste Management Rules, 2016
- Landfilling of waste contaminated with hazardous material in composite liner HDPE geo-membrane.

Sadly, the SWM rule never specifies any separate segregation or deposit center for batteries and all provisions are directed for aggregated domestic hazardous waste. There is no mandate for EPR also for small battery producers or even recycling of the battery resources through any other formal network.

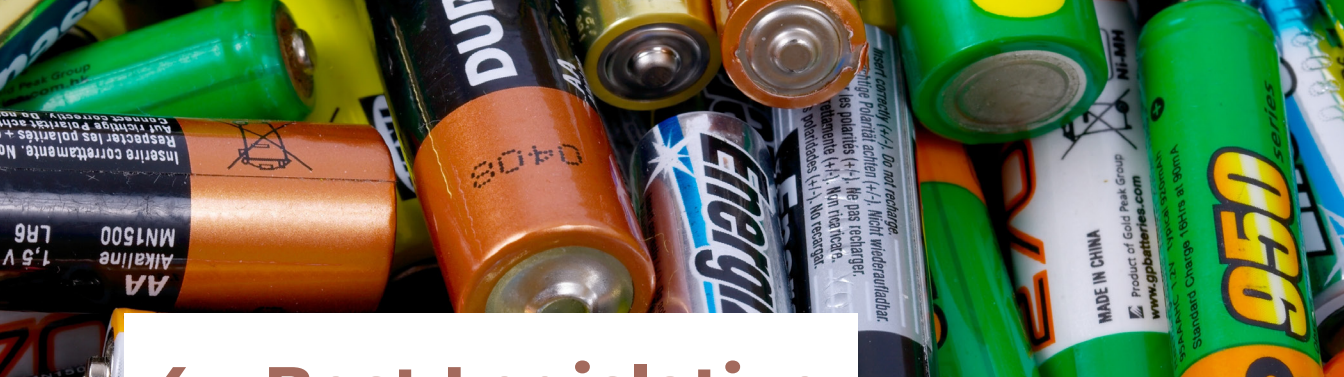
The rule mentions to stop land filling or dumping of mixed waste once the sanitary landfills are set up and in operation (timeline 1 year from the time of implementation of the rule). It also says, “allow only the non-usable, non-recyclable, non-biodegradable, non-combustible and non-reactive inert waste and pre-processing rejects and residues from waste processing facilities to go to sanitary landfill.” Hence, according to the rule, batteries shall go to the hazardous waste disposal facility. But they are not recycled as of now and most likely end up in the landfill as pre-processing rejects from the waste processing facility.

The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2015 on the other hand do not restrict waste batteries (excluding those containing lead, cadmium & mercury) import and export under part B of Schedule III following the Basel Convention provisions. Used batteries other than the lead acid batteries are also listed as commonly recyclable hazardous waste under Schedule IV of the Rule.

Mere mention as recyclable waste in the hazardous waste rule does not save their fate as secured land-filling is the only provision made under the regulations for small battery waste. India has only 17 hazardous waste disposal facilities with secured landfill and no formal recycling units for used batteries yet they are free to come inside the country from other countries. Also, in the ground level implementations of the existing rule, provisions for household hazardous waste are very poor and close to zero. The country lacks in both legislating and enforcing end-of-life small battery management.

Like many other products, batteries also follow a linear lifecycle, beginning as raw materials in the earth, passing through refining, manufacturing, use, and finally returning to the earth in a landfill. While this linear lifecycle has been the norm, the increasing environmental concerns are of immediate need to be addressed. The overburdening of landfills and mounting pressure on the limited natural resources have drawn attention towards closing the resource loop instead of continuing with linear chains. To address this, adding loops to the linear lifecycle, often in the form of reuse, remanufacturing, and recycling of batteries are strongly recommended.

Battery directives in Europe and Canada and waste classification legislation in California have intensified discussions about end-of-life battery regulations all over the world. These legislations have pushed for the recycling of battery waste. Many life cycle assessments have shown that recycling programs reduce the impact of batteries at end-of-life when compared to land filling. Though safe disposal and recycling of the domestic battery waste was recognised in developed countries way back in the nineties considering the consequence of their increased consumption, India still lags far behind in addressing them.



4. Best Legislative Frameworks and Collection and Recycling Practices in the World

Battery take-back legislations regulating the manufacture, collection, recycling and disposal of batteries are proved to be the most effective way to address their environmental impacts. This has been mandated by the European Union and in countries like Japan, Taiwan. In most of the developed world, battery recycling is carried out in the formal sector by private enterprises. (Advanced chemical processes and sophisticated machineries are used for dismantling to facilitate efficient resource recovery.) A proper collection system is in place in accordance with their rules and regulations. Some of the best practices across the globe are presented below.

India has no separate regulation for small battery waste management

4.1. USA

United States Environmental Protection Agency (USEPA) has enforced federal universal waste regulations to streamline certain categories of hazardous waste management. Batteries, Pesticides, Mercury-Containing equipment and Lamps are the four types of universal waste according to the regulation. The regulated participants of this universal waste system are also of four types, viz., small quantity handlers, large quantity handlers, transporter and destination facilities. There are labeling requirements for recycling in the products, prevention on release in the environment, response to release and transportation facility to recyclers or hazardous waste receivers. However, the safe disposal of the batteries, according to their types, was framed in the US way back in 90s (Table 6).

Table 8: Safe Disposal Rules for Household Batteries in USA³²

Battery Type	Common Name	Available sizes	Examples	Disposal Classification	Ideal disposal methods
Alkaline (Mn)	Cookertop, alkaline	AAA, AA, C, D, 6V, 9V	Flashlights, calculators, toys, clocks, smoke alarms, remote controls	non-hazardous waste	Place in the trash (normal municipal waste). Exceptions: California which requires non-households to dispose of these batteries in accordance with the California Universal Waste Rules.
Button	Mercuric Oxide, Silver Oxide, Lithium, Alkaline, Zinc-Air	Different sizes	Watches, hearing aids, toys, greeting cards, remote control	Hazardous waste	Keep them separate from non-mercury batteries and tape their terminals. Take it to a household waste collection site
Carbon Zinc	"Classic", Heavy Duty, General Purpose, All Purpose, Power Cell	AAA, AA, C, D, 6V, 9V	Flashlights, calculators, toys, clocks, smoke alarms, remote controls, transistor radios, garage door openers	Non-hazardous waste.	Place in the trash (normal municipal waste). Exceptions: California requires non-households to dispose of these batteries in accordance with the California Universal Waste Rules. Also, Minnesota (Hennipen County only) requires these batteries be disposed as a hazardous waste.
Lithium / Lithium Ion	Usually has "lithium" label on the battery	3V, 6V, 3V button	Cameras, calculators, computer memory back-up, tennis shoes	non-hazardous waste	Completely discharge them and tape the ends before giving them away for recycling. If disposed of without fully discharging them, they could cause fires.
Nickel-Cd (Rechargeable)	Either unlabeled or labeled "Ni-Cd"	AAA, AA, C, D, 6V, 9V	Flashlights, toys, cellular phones, power tools, computer packs	hazardous waste	Take it to a household hazardous waste collection site
NiMH (rechargeable)	Either unlabeled or labeled "Ni-Li" or "Ni-Hydrile)	AAA, AA, C, D, 6V, 9V	Flashlights, toys, cellular phones, power tools, computer packs	non-hazardous waste - except in California. California Universal Waste Rules mentions them as Universal waste batteries exhibiting characteristic of hazardous waste.	Safe for disposal in the normal municipal waste stream. These batteries are also acceptable for recycling by Rechargeable Battery Recycling Corporation (RBRC)
Reusable Alkaline Manganese (Rechargeable)	AAA, AA, C, D	Flashlights, calculators, toys, clocks, radios, remote control	Flashlights, calculators, toys, clocks, radios, remote controls		Dispose of with household trash

32 Battery Recycling and Disposal Guide for Households..Available at <http://www.ehso.com/ehshome/batteries.php>

The Battery Act (Mercury-Containing and Rechargeable Battery Management Act) came in 1996 in the USA. It facilitates the increased collection and recycling of Ni-Cd and certain small sealed lead acid (SSLA) rechargeable batteries. It establishes, a) labeling requirements, b) mandates the batteries to be easily removable, c) makes the Universal Waste Rule effective for the collection, storage, and transportation of batteries covered by the Battery Act and d) requires EPA to establish a public education program on battery recycling, handling and disposal.³³

4.1.1 COLLECTION AND DISPOSAL METHODS IN USA

'Call2Recycle' is the first and most widely spread end-of-life household battery recycling programme in North America. The programme, having presence in 48 states in the continent, was developed by the Rechargeable Battery Recycling Corporation (RBRC) –a nonprofit one based in the USA. The programme has been operational for over 20 years and has recycled more than 100 million pounds of batteries with 30,000 drop-off collection sites across US and Canada. Nickel cadmium, nickel metal hydride, nickel zinc, lithium ion, small sealed lead acid and single use batteries including alkaline and lithium primary are recycled through the programme to keep them out of the solid waste stream and prevent toxins from ending up in landfills or municipal incinerators. The recycling plans are different for different stakeholders. There are provisions for free drop-off recycling networks, becoming collection partners under the pay-as-you-go facility, industrial stewardships to promote responsible recycling, recycling by organizations through payment, etc. Collected batteries are sent for sorting, processing and recovery. The program sends all nickel rechargeable, alkaline and zinc primary cells to the International Metals Reclamation Company in Pennsylvania. Waste disposal is according to Responsible Recycle (R2) and Basel Action Network (BAN) standards.

Following is a flow chart of the strategy and operations of Call2Recycle³⁴:



³³ United States Environment Protection Agency (USEPA). Implementation of the Mercury-Containing and Rechargeable Battery Management Act. Available at <https://www.call2recycle.org/wp-content/uploads/ImplementationoftheMercury-ContainingandRechargeableBatteryManagementAct.pdf> accessed on 12.06.2018.

³⁴ Call2Recycle. <https://www.call2recycle.org/flow-chart/>



Battery Process & Recovery Partners

Cobalt, nickel, stainless steel, cadmium, lead, zinc, carbon, lithium, manganese and other metals are recovered by different processing & recovery partners

Cellphone Process & Recovery Partners

Refurbished/resold or materials recovered

4.1.2 RECYCLING

NiCd batteries are recycled using a high-temperature process. The process was initially developed to recover metals from dust in electric arc furnace but later its application widened to recover metals from other kinds of waste too. The cadmium recovery facility used by INMETCO, as well as the SNAM-SAVAM (a French battery recycling company) and the SAB-NIFE (a Swedish company) is based on **cadmium distillation**. It separates nickel and iron from the cadmium. Recovered nickel is shipped to steel producers for use in stainless steel products. Cadmium remains in the dust with zinc and lead is sent for further recycling. The recovered cadmium, at a 99.95 percent purity level, is used to produce new Ni-Cd rechargeable batteries.

BATENUS process is another method developed for treating **dry cell battery** mixtures (zinc-carbon, manganese-alkaline, nickel-cadmium and lithium) in the US. The process consists of many steps of mechanical and hydrometallurgical processing techniques. Automatic sorting of batteries is carried out and individual streams of batteries with different composition are generated. Batteries containing mercury are separated and treated alone. The batteries become brittle after treatment with cryogen and fractions of different size, density and magnetic characteristics are separated. The resulting black powder is leached using sulfuric acid and the metals are recovered by electrolysis and electro dialysis.

4.2. EUROPE

The European Commission has legislated a Battery Directive in 2006 on Batteries and Accumulators and Waste Batteries and Accumulators. The directive, developed through public consultation, extended impact assessment, and a special conciliation process to ensure appropriate collection and reuse of batteries, applies to all batteries. It has rules for collection, recycling, treatment and disposal of batteries and restricts mercury and cadmium content in batteries up to 0.0005% (5 ppm) and 0.002% (20 ppm) respectively. The directive

sets phase wise collection targets (25 percent by 2012 and 45 percent by 2016) and recycling efficiency targets (65% for lead acid batteries, 75% for nickel cadmium batteries and 50% for all other types), minimum rules for producer responsibility and labeling provisions. It recommends the member states to transpose the directive into national law for facilitating collection to end users and treating and recycling of the collected batteries using best available techniques.³⁵

4.2.1 COLLECTION MODELS IN EUROPE

Many countries in **Europe** have national schemes to manage the different types of hazardous and non-hazardous batteries. In these countries, battery manufacturers, retailers, equipment manufacturers and importers, are responsible for funding the waste battery collection models.

Following are some operational **collection models in Europe**:

- 1. State Fund Model:** The only responsibility of producers under this model of waste management is to provide funding for the collection models. Producers have to pay fees to a designated waste management fund, or funds are collected through taxation. The decision about the waste battery collection operations to be funded by a producer has to be taken by a government organization, municipal or regional authority. This model may have different sub-types- the battery management model may be clubbed with some other waste management project, or single purpose models dedicated to only battery waste management also exist.
- 2. Single organisation (Environmental agreement) model:** In an 'environmental agreement' with the government, the entire manufacturing sector has the duty of funding and organising waste battery management through a single organisation. If the industry fails to meet mandatory collection targets, legislation is in place to enforce taxation on battery producers.
- 3. Competing organisations model:** Government authorises several organisations to assume the take-back obligation of producers. Organisations compete with each other with respect to the fees charged from producers, to cover the cost of battery waste management and to take it to collection targets. But, the risk of inaccurately reported data increases with the number of supply and trading relationships between

³⁵ European Union. 2006. Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC.

organisations, collectors and waste traders. There may also be trust issues between different organizations.

- 4. Model without organisations:** Each producer finances authorised waste battery companies (collectors and transporters) directly to meet the collection targets imposed on him. There are no legal provisions for authorizing organisations to coordinate battery waste management on behalf of producers. However, battery producers there comply through service providers that fulfill a similar role as collective organisations while the take-back obligation is retained by the individual producer.

4.2.2 RECYCLING PRACTICES IN VARIOUS COUNTRIES IN EUROPE

By the end of 2016, European countries like Slovakia, Luxembourg, Belgium, Sweden and Germany among many others had achieved the target of 45 percent collection rate for batteries as mandated by the EU directive³⁶. In **Sweden**, battery collection boxes are attached to paper collection containers and the truck which collects the paper collects batteries as well.

In **Germany**, battery producers, legally obliged to collect their products from consumers, collect through the nationwide containers of GRS Batteries Foundation. GRS sends the filled containers to sorting facilities for recovery of valuable materials and metals according to their electrochemical class. **NIREC**, a company in **Germany**, has developed a recycling process based on material separation (called '**mineral processing** techniques') by means of **vacuum milling**. Nickel is separated and sent as raw material for secondary metallurgy. The system places procedural emphasis on the separation, reclamation and use of the high-quality nickel content, and the potential risk of hydrogen. Due to the possibility of Hydrogen being released when NiMH batteries are pound, the processing must be performed in a vacuum environment. Using a vacuum system, the batteries are passed through a cutting chamber, which opens up the casing and releases the stored hydrogen, which is constantly drawn off by the difference in pressure. The batteries then land in a collecting container. After a stabilization period monitored by sensors, and then aeration to render it inert, the material can then be taken out. After separation of the plastic content, a usable product is obtained with a high nickel content, which can then be reused as a significant alloying component in stainless steel production. For **Lithium batteries**, the **Toxco** process involving cryogen embitterment is used.

36 <https://www.recyclinginternational.com/recycling-news/9835/e-scrap-and-batteries/europe/eu-struggles-towards-45-battery-collection-target>

In **Belgium**, the company **MMM-Sedema** has developed a process for recycling of **zinc-carbon** and **manganese-alkaline batteries**. The batteries are mechanically processed to recover a metallic fraction (magnetic and density difference separation). The waste generated in this process consists of a black powder composed basically of carbon, manganese and zinc. The powder is leached and a solution rich in manganese and zinc is produced. The solution is purified and manganese and zinc salts are produced.

The process **AED** has been developed for the recycling of **lithium batteries**. The process uses grinding techniques for the separation of materials and cobalt reduction reactions at room temperature. SONY process, which recovers cobalt after an incineration step, is also in use to recycle lithium batteries. The Mülheim-based Company, **ACCUREC**, in **Germany** has developed a method of recycling which is done using **vacuum distillation (Recycling through Vacuum Distillation or RVD)** for lithium manganese oxide (LiMnO₂) batteries. The same process can also be carried out for recycling Nickel Cadmium batteries, which produces Cadmium and ferronickel alloys. **SNAM** in France also offers a reprocessing procedure based on pyrolysis and magnetic separation for lithium secondary systems.

The **imperial smelting process (ISP)** in Duisburg has evaluated the recycling of **zinc-carbon and zinc-air batteries** on zinc production in Germany. The ISP has Zinc as the main product and is already operating with different zinc concentrates as raw material. Another process in Germany for batteries containing zinc is the **WAELEZ** process, used in the recovery of metals from dust by means of a rotary furnace. It is possible to recover Zn, Cd and Pb.

In **France**, the company **CITRON** has developed a recycling process, also based on pyrolysis and metal reduction techniques, where different materials can be treated after mechanical processing.

NiCd batteries are treated usually in a separate process due to two important reasons: the presence of cadmium that causes some difficulties in the recovery of mercury and zinc by distillation, and the metallurgical difficulties associated with the separation of nickel and iron. Different processes were then created for NiCd battery recycling. In **France**, it is done by the **SNAM-SAVAM** process and **Sweden** uses the **SAB-NIFE** process. Both processes use a totally closed furnace, where cadmium is distilled at a temperature between 850 and 900 °C. It is possible to obtain 99.95% pure cadmium condensate. Nickel is recovered in electric furnaces by reduction. The production of cadmium oxides in open furnaces is not used due to safety problems.

4.3. CANADA

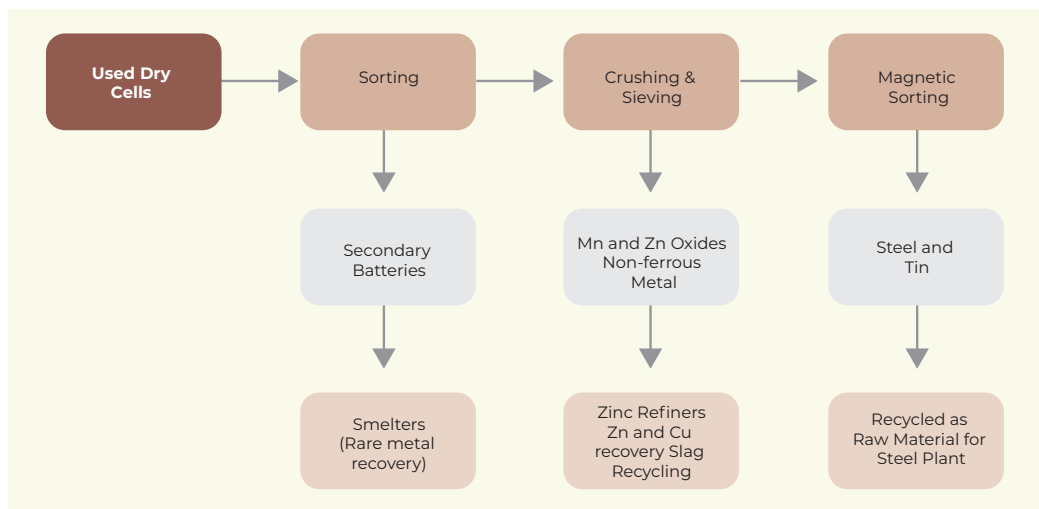
Canada does not have any general extended producer responsibility legislation. British Columbia, Quebec, Manitoba and Ontario have regulations which have made recycling of all types of primary and secondary batteries mandatory. The regulations obligate brand owners and first importers to pay fees for collection and safe disposal of batteries. In Canada, largely Call2Recycle operates with its stewardship programme similar as of the USA. Consumers can drop off the used batteries to any Call2Recycle collection sites without any charge.

4.4. JAPAN

Japan is one of the very few countries in Asia having EPR (Extended Producer Responsibility) rules but only for rechargeable batteries. The Japanese Law for the Promotion of Effective Utilization of Resources (2000) specifies the manufacturers and importers of rechargeable batteries and the product lines to apply comprehensive 3R (reduction, reuse and recycling) measures. The provisions in the law includes, a) 3R related measures for product design and production stage, b) specific labeling by types of batteries for collection improvement, c) development of collection and recycling system by manufacturers. This approach aims to shift the end-of-life product responsibilities upstream to the producers by incorporating environmental considerations into product design. Statutory recycling targets for recovery rates of rechargeable batteries are set by the 'take-back' EPR legislation which is 60 percent for Ni-Cd, 55 percent for Ni-MH, 30 percent for Li-ion and 50 percent for SSLA batteries. Japan Battery Recycling Centre (JBRC) – an authorised Business Entity of Specified Resources-Recycling Product by the Ministry of Economy, Trade and Industry and the Ministry of Environment of Japan, was established in 2004 to fulfill the producers' recycling obligations. JBRC consists of manufacturers of both compact rechargeable batteries and equipment using such batteries. It has over 8000 consumer collection sites and 60 Local Government collection sites in the country. Collected batteries are forwarded to specific recyclers for recovery of cadmium, nickel, iron, copper, cobalt, aluminum, etc.

There are some other entities as well who are directly engaged with dry cell recycling post the municipal separation of batteries. Nomura Kohsan Co., Ltd and JFEKanyo Corporation are in operation for a long time. **JFEKanyo Corporation** collects spent dry cell batteries and detoxifies hazardous materials to recycle resources. Collected dry cell batteries are separated into steel and non-ferrous metals. The steel content is recycled as steelmaking material. Zinc is extracted as a resource from the other non-ferrous metals at a non-ferrous metal refinery. Other metals are converted to melted slug and recycled as cement material. The figure below shows the entire value chain of used dry cells from collection to recycling:

Dry Cell battery recycling by JFE Kanyo Corporation (Japan)³⁷



Nomura Kohsan Co. Ltd. is also involved in dry cell recycling. Their process involves roasting (in rotary kilns) after sorting followed by pulverization (grinding to dust) and magnetic separation. After this, a black powder consisting of Zinc and Manganese is obtained which is used to make Zinc ingots and micronutrient fertilizers. The outer casings are recycled to obtain iron which is then sent to ironworks.

Apart from these processes, there are other methods to recycle different types of dry cells to ensure maximum recovery of useful material. **SUMIMOTO**, a Japanese process created for portable batteries, applies pyro-metallurgy and is used in the recycling of all types of batteries with the exception of **NiCd** batteries. It is based on a pyrolysis stage, where mercury is recovered from the generated gas in a reduction stage, zinc is recovered as a dust and a ferromanganese alloy is produced. The Swiss company **BATREC** modified the **SUMIMOTO** process where any waste containing heavy metals (batteries, dental wastes, thermometers, scraps, etc.) are treated.

4.5. AUSTRALIA

Battery recycling in Australia is currently voluntary. New law compelling manufacturers to collect and recycle used batteries are in consideration by the Australian Environment Ministry. However, the Australian Battery Recycling Initiative (ABRI), a group of battery

³⁷ Recycling of Dry Cell batteries/Storage batteries. By JFE Kanyo Corporation, Japan. Available at <https://www.jfe-kankyo.co.jp/en/business/products/battery.html> Accessed on 12.06.2018.

manufacturers, recyclers, retailers, government bodies and environment groups, promotes responsible end-of-life battery management through collection, recycling and safe disposal of all batteries. ABRI is negotiating for a national voluntary stewardship programme with the industries and the government stakeholders for handheld batteries. A multi-stakeholder Battery Implementation Working Group (BIWG) is formed for commencement of various actions in this regard.

ABRI has an area wise recycling service locator which provides battery drop-off locations for free recycling of handheld batteries. Besides, Sydney City Council, Sustainable Victoria and several other Councils collect batteries through their collection bins. Battery World stores, a retail franchise network in Australia and ALDI supermarket also offer free battery recycling services for their customers. ALDI has started the collection initiative as part of their CSR (Corporate Social Responsibility). They have designated recycling bins for different types of household batteries. The batteries are collected by their specialist recycling partner, sorted into chemical types and returned to recycling plants who extract relevant materials for re-use.



5. Conclusion and Recommendations

- Batteries provide a portable power source for many of the products that have become important to our changing way of life. Mobile phones, smoke detectors, flashlights, remote controls, cordless telephones, LED lights, children's toys, gaming systems and digital cameras are just a few of these devices using these convenient source of power. And the list of items powered by single use and rechargeable batteries continues to grow and change. However, batteries have impact on the environment at every stage of their lifecycle. The metals used to manufacture batteries are non-renewable finite resources, and mining and processing of metal ores is energy-intensive. Batteries have environmental impacts at the end of their life. While most automotive batteries are recycled, the majority of 'DEAD' small batteries still go to landfill. In poorly managed landfills, batteries have the potential to leach toxic heavy metals into the surrounding soil, surface and groundwater.
- Batteries, especially the 'single use' ones have a huge market across India. According to The Association of Indian Dry cell manufacturers (AIDCM), the rural areas accounted for majority of the volume sales share of the Indian dry cell battery market. This means that the battery consumption and hence battery waste is quite spread out. With no systems in place even in metro cities, it is clear that in rural areas the batteries are probably dumped in fields, thereby raising the concern about leaching out of toxic materials not just in landfills but also in agricultural fields.
- Recycling standard portable batteries powering a torch or a toy can yield a wealth of secondary materials such as iron, zinc and ferromanganese. Recycling has the ability to generate a substantial and growing resource, and will become more economically viable as virgin resources are depleted and become more expensive. It also has other environmental benefits. Using recycled rather than virgin materials avoids the environmental impacts associated with mining, such as land degradation, waste and

energy use. The manufacturing of recycled materials requires less energy and generates less pollution than the manufacturing of virgin materials. Current disposal system of batteries in India is certainly not geared towards recycling and resource recovery.

- This report is an attempt to understand and flag off the concern related to improper disposal and recycling of these small batteries. The study has also looked at the possibility of resource recovery, especially since circular economy is gaining prominence and is key to sustainable living.
- The study findings clearly spells out that household battery waste management is a concern which needs to be looked at. Though the battery constituents have changed overtime and there have been attempts globally to make these less hazardous, it still has toxic materials and needs to be carefully managed. The current study indicates that the volume of small battery waste is huge in the country and it is unmanaged. Framework of Solid waste management, which included these small batteries as household hazardous waste, has failed to address the issue and there has been no collection or recycling infrastructure triggered by the policy.
- Though there might have been attempts by some municipalities in the country, overall there has been little action taken by the authorities to set up any collection or disposal system for this waste stream. During the study, the team also did not come across any voluntary initiative by battery companies to collect and manage the waste arising from the small batteries. Lack of Product stewardship programmes for small batteries mean that almost all of the used or spent batteries are managed or disposed of in an unsafe manner.
- The informal recycling, which was primarily handling this waste till few years back, has also hit roadblocks, which means that the waste is currently completely relegated to landfills. The already brimming landfills in cities are now being further burdened by these batteries. This improper disposal unnecessarily squanders resources and energy, represents a missed opportunity for recycling jobs, and can result in groundwater and air contamination. Also, though the study did not investigate this aspect, there might be huge concerns of low quality batteries being dumped in the country.
- In a huge country like India, some of the barriers to be overcome include the high costs of collection and sorting. Economic feasibility of recycling technology will need to be also evaluated. But the biggest trigger has to come from the regulatory framework. Since the current solid waste charter has completely failed to prompt any action on ground, it is probably time to examine if solid waste rules are adequate and able to address the complicities of household hazardous waste like batteries. A separate framework might be able to be more effective.

5.1. KEY FINDINGS

- The dry cell battery volume in India is 2.7 billion pieces every year. ZnC cells constitute 97 percent of the dry cell market in India with alkaline batteries and others constitute the remaining 3 percent.
- Maximum use of the dry cell batteries in the households is for TV remotes, flashlights, watches, toys, AC remotes and cameras.
- Since used dry cell batteries generated contain recoverable resources, like, zinc, graphite rod, tin, manganese dioxide, carbon powder, etc., efficient recovery can extract 18 percent of zinc by weight from used batteries. Unskilled informal recovery also can reportedly extract 5 percent zinc by weight which makes it 15,025 tonnes of Zinc that could be recovered from the current consumption of batteries. Along with that 15,258 tonnes of Manganese and 10,848 tonnes of steel along with 2.4 billion graphite rods can be recovered in India every year, only by recycling ZnC cells. These can be melted and used again for a variety of purposes.
- Recycling of the small dry cell batteries in India is informal, very limited and almost negligible. Though segregation of these batteries is mandated in the solid waste rules disposal methods are not described. There is no Extended Producer Responsibility (EPR) for these battery producers. Most of the annual zinc-carbon cell consumption eventually goes to landfills every year in India and the number can amount to about 2.4 billion pieces.
- Resource Conservation Potential: 15 GJ of energy is required for the production of 1 tonne of Zinc. Apart from consuming large quantities of energy and water, smelting and other extraction processes pollute the environment to a great extent. Research has shown that using only recycled Zinc can reduce the environmental load by 90 percent since recycling Zinc consumes 76 percent less energy. Similarly, huge savings on our natural resources is possible by using recycled Manganese, steel, carbon and other elements and alloys along with prevention of detrimental impact on the environment.

5.2. RECOMMENDATIONS

In the absence of a specific regulatory framework in place and voluntary action by battery manufacturers, battery recycling in India is almost non-existent. To change this, a target set 'take-back' or EPR legislation for the battery manufacturers and retailers are of immediate need. This will also prompt introduction of appropriate technologies and creation of

organised recycling facilities to ensure efficient and maximum resource recovery.

Through battery extended producer responsibility (EPR) programs, manufacturers can provide consumers with a convenient way to responsibly manage discarded batteries. With producer funding, EPR can offer an effective, sustainable financing system that increases the collection and recycling of leftover batteries, reduces government and overall costs of battery management, and lessens environmental impact.

Though this report did look at the economics of recycling in the informal sector, further studies would help us understand the recycling sustainability in a formalized space. Efforts have to be made to support recycling through government subsidies, product stewardships and disposal costs.

Also, in recent years, with more and more active battery chemistries being developed, both the safety in handling and segregation according to the chemistry is important. In particular, the presence of corrosive electrolytes, highly ignitable or explosive battery materials under certain conditions and toxic heavy metals have become an issue which the battery industry must address. Upstream regulation for battery constituents, design and labeling requirements are key to reducing impacts.

Success depends on consumers handing in their waste batteries for recycling, so consumer awareness is crucial. In countries doing better, more is being spent on TV and radio advertising and programmes involving schools. In Belgium, for example, almost a quarter of batteries are collected from schools. Belgium's battery collection organisation, Bebat, runs a programme that enables schools to collect points for each kilogramme of batteries collected. These points can be exchanged for prizes such as sports equipment and entry to museums. In the Netherlands, consumers who return 10 batteries to be recycled at local collection points in supermarkets and other stores are entered into a nationwide monthly draw for €1,000 (£801) travel vouchers and other cash prizes. Some of these initiatives and incentives can help in bringing in consumers to a clean system. Unlike lead acid battery or e-waste

EXTENDED PRODUCER RESPONSIBILITY

Producers are financially and organizationally responsible for the proper management of products during collection, transport, storage, processing, reuse, recovery and/or final disposal. They assume the costs of separate collection and environmentally responsible management of waste. They are also in charge of designing and paying for any public information campaigns needed to raise awareness of the scheme. Producers can fulfill their obligations individually or as a group under a collective scheme.

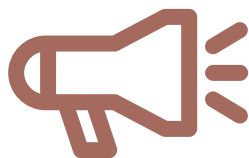
where the monetary considerations have been a big barrier, since batteries are currently disposed of, in majority of cases, as waste (that is without any monetary exchange), it will probably be easier to achieve success in takeback, But the consumers should be informed of the segregation methods at the household level, facilities for drop-off, benefits of battery recycling and their invaluable role in reducing their impact on the environment and health.

In India, the un-organized sector has until now played a key role in collection and recycling of spent dry cell batteries. The evolving framework could be inclusive of the informal chain of collectors and segregators.

KEY RECOMMENDATIONS

- A separate regulatory framework for small batteries management
- Target based Extended Producer Responsibility as the key principle
- Setting up of robust collection mechanism for consumers
- Support for battery recycling infrastructure
- Consumer awareness

The key is controlling of the material flow of batteries with the establishment of recycling targets and the development of a framework for funding collection schemes. Best practices from different countries could also be adopted to develop a nationwide comprehensive labeled battery manufacturing, end-of-life battery collection, recycling and safe disposal system.



Think before you toss that battery in the dustbin!

When a battery dies, you take it out of the device and throw it in the dustbin? That trash ends up in a landfill, not just filling up the landfill but also polluting our surroundings.

If not properly disposed of, batteries come at a HUGE cost to the environment.

ACKNOWLEDGEMENT

We would like to thank Mr. Ravi Agarwal, Director, Toxics Link for his continued guidance and encouragement. We would like to thank Mr. Satish Sinha, Associate Director, Toxics Link who guided us through the entire research process and helped us in shaping the study and the report.

We are thankful to ASUME (Awareness of Social Unit and Market Evaluation) for carrying out the assessment of end-of-life battery flow value chain.

Our sincere thanks are also due to all team members of Toxics Link for their valuable inputs and suggestions.



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