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Hazardous Effects of Battery Waste and Role of the Battery Waste Management Rule 2022 in Enhancing Energy Efficiency

Abhijeet Kumar[1*], Dr Firdaus F. Rizvi[2]
[1*]Research Scholar, Department of Development Studies and policy, Central University of South Bihar, Gaya, Bihar
[2]Faculty, Department of Economic Studies and Policy, Central University of South Bihar, Gaya, Bihar

ABSTRACT: Replacing batteries in present world is challenging because they are extensively utilised in every facet of human existence. These batteries contain a variety of toxic heavy metals, including as cadmium, copper, lead, mercury, nickel, and zinc, all of which pose risks to human health and the environment. Improperly disposing of used batteries in landfills leads to the infiltration of toxic heavy metals and other dangerous compounds into the soil and water over time. India's long-term development has significant challenges in both reducing CO2 emissions and meeting the energy demands of its large population. This has significantly bolstered the electric vehicle (EV) and renewable energy industries. Battery-based energy storage systems can enhance the management of operational and energy evacuation challenges associated with renewable energy. Consequently, the effective disposal of battery waste is more crucial than battery production. However, it is neglected often, specially in developing and impoverished nations. Three established methods exist for preventing and managing the issues arising from the inappropriate disposal of used batteries. The three R's are: decrease, replenish, and reuse. This article initially analyses the health and environmental consequences of battery waste, and subsequently highlights the potential of new regulations on battery waste management to effectively handle huge amounts of battery waste and encourage energy conservation.

KEYWORDS: Battery waste, Battery waste management Rule, Electric Vehicle, Human and Environment.

INTRODUCTION

Today, wireless devices like Smart phones, computers, watches, and remotes dominate our lives. These devices really affect our life. Batteries or cells power most of them. Wireless devices require power, hence they cannot be built without batteries. Electric vehicles and space exploration require batteries. Batteries are essential to human life and will be used everywhere. These applications include timepieces, computing devices, auditory aids, medical devices and implants, handheld illumination devices, playthings, handheld machinery, portable communication devices, video recording devices, portable computers, handheld tablets, personal transportation devices, motorised vehicles, missiles, underwater vessels, satellites, aircraft, spacecraft, supplementary and emergency power sources, uninterrupted power (*The Impact of Mobile Technology In Our Lives*, 2021). The government has given priority to the implementation of electric vehicles in order to advance the use of clean energy and foster ecologically sustainable progress. Electric Vehicles (EV) are automobiles that exclusively depend on rechargeable battery packs to store and utilise chemical energy, without any supplementary methods of propulsion. Battery electric automobiles do not have an internal combustion engine, fuel cell, or fuel tank. The vehicles encompassed by this classification are trucks, cars, buses, motorbikes, bicycles, and forklifts. Different types of batteries are used to provide electricity to electric vehicles. The selection of the optimal battery relies on various criteria like its energy storage efficiency, production costs, structural characteristics, safety measures, and lifespan..(Keerthi, n.d.)

A battery is a device to transform the chemical energy contained in its active materials directly into electrical energy by means of an electrochemical oxidation-reduction (redox) reaction (Linden & Reddy, 2002). Batteries possess a distinctive mechanism characterized by the absence of any movable components, yet they are capable of facilitating the flow of electric current inside circuits. Batteries are typically divided into two main categories: primary non-rechargeable batteries (such as zinc-carbon, magnesium-manganese dioxide, alkaline-manganese dioxide, alkaline zinc-mercuric oxide, cadmium-mercuric oxide, zinc-alkaline electrolyte-silver oxide, zinc-air batteries, lithium-sulphur dioxide, lithium thionyl chloride, lithium-sulphuryl chloride, lithium-manganese dioxide, lithium-silver vanadium oxide, lithium-iodine, etc.) and secondary rechargeable batteries (such as

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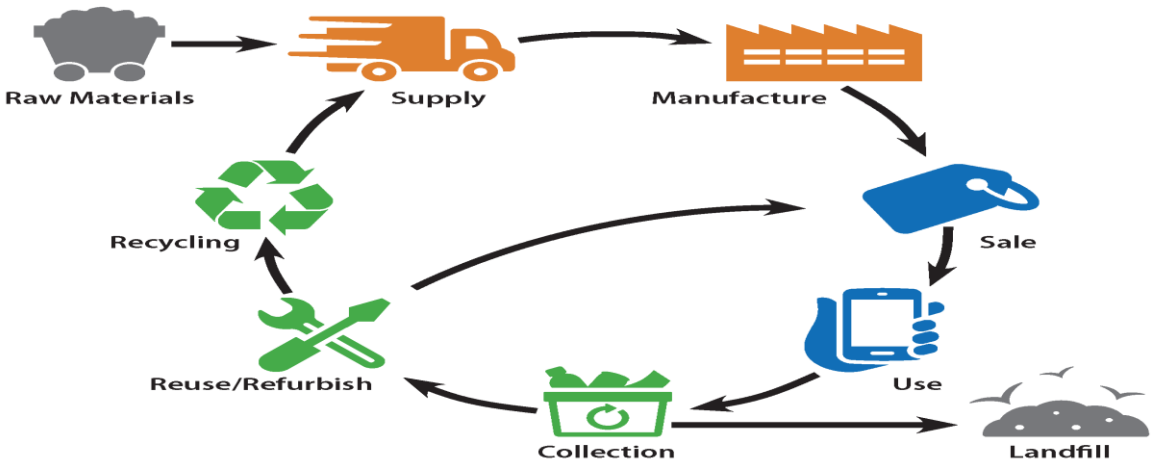
lead-acid, nickel-iron, nickel-cadmium, nickel-zinc, nickel-hydrogen, zinc-silver oxide, cadmium-silver oxide, iron silver oxide, zinc-alkaline-manganese dioxide, etc.), depending on their ability to be electrically recharged.

Battery Waste can be effectively segregated

Humans generate millions of tonnes of waste annually; this is increasingly recognised as a matter of international concern. The delivery of efficient waste collection and disposal systems by governing bodies has emerged as a progressively imperative need in light of the substantial volumes of waste being generated. Statista reports that despite this, only about 20% of waste is recycled annually, while immense quantities remain disposed of in landfills. Moreover, waste is frequently disposed of in hazardous landfills, particularly in developing countries. Waste segregation effectively mitigates the volume of waste deposited in landfills, thereby promoting ecological sustainability and economic viability for both human beings and the environment. Moreover, waste segregation is an essential public health measure. Particularly hazardous wastes possess the capacity to induce chronic health complications; thus, their appropriate and secure disposal, separate from household or office garbage, is of the utmost importance. Waste segregation is of the utmost importance due to the fact that solid, semi-solid, liquid, biodegradable, and non-biodegradable wastes must be separated in order to be disposed of separately according to their characteristics.



Source:(US EPA, 2019)

Given the extensive use of diverse battery types in everyday life, a significant amount of battery waste will be generated, and each form of battery requires its own specific technique of recovery and disposal. They possess a range of noxious and erosive compounds such as lead, lithium, mercury, and cadmium. Every category of batteries exhibits a notable recycling rate. Internally, it is advisable to maintain a clear distinction and handle them with care during disposal. Lithium-ion and lead-acid batteries are addressed separately. The batteries are disassembled into their respective components. Disposing of batteries will result in significant ecological harm. Currently, the predominant methods used for treating waste batteries include cremation and land-filling, solidification treatment, manual sorting, moist recovery technology, dry recovery technology, and bio-metallurgical technology. The existing regulation specifically prohibits the mixing of hazardous trash or waste containing high concentrations of persistent organic pollutants (POPs) with nonhazardous waste or other hazardous waste .

The are the advantages of proper waste segregation of Battery waste :

Reduced Waste Costs: The cost of combining refuse streams can be substantial. The disposal costs of hazardous garbage and general waste are considerably higher in comparison to dry mixed recycling due to the presence of chemical and biological pollutants. As a consequence, the disposal costs of clean recyclables that are mixed with hazardous waste ultimately increase.

Increased Recycling Rate: Methods of waste segregation and an employee base that recognises the importance of segregating trash prevent recyclable materials from being disposed of with regular garbage.

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Potential Revenue Streams: By identifying valuable materials such as cardboard, plastics, and metals, waste sorting generates a rebate value from the generated garbage.

Reduced Landfill Impact: By sorting trash, individuals can increase the amount of recyclable materials and prevent their disposal in landfills. Consequently, this mitigates the detrimental impacts of waste on the environment as a whole.

Hazards due to improper Battery Waste Management

A chemical or physical condition that has the potential to cause damage to people, property, or the environment is termed as a Hazard (Crowl & Louvar, 2002). A battery that is no longer wanted or is unusable for its intended purpose and is intended for storage, recycling or disposal is termed as a waste battery (*Waste_batteries_2011*). Most of the batteries contain toxic heavy metals such as mercury, cadmium, lead, nickel, zinc, or copper, which are all hazardous to human health and environment. However, the Basel Convention considers only the batteries containing cadmium, lead and mercury as hazardous. While the batteries that do not contain cadmium, lead or mercury such as alkaline manganese and zinc carbon are classified as non-hazardous (*Treatment of Batteries within the Basel Convention, 2009 (Www.Nema.Org*.).

Disposing of waste batteries in the trash results in their deposition in landfills . The presence of hazardous heavy metals and compounds in these batteries can lead to environmental contamination through the process of leaching, which involves the release of these substances into soil and water. This contamination can result in the pollution of water bodies, rendering them unsuitable for use by both humans and wildlife. During the process of incineration, specific hazardous metals have the potential to be emitted into the air through stack gases or to build up in the ash resulting from the combustion. The possible effects of hazardous battery wastes on human health and environment are given in Table :-

Health Impacts on Humans and Environment

Component	Source	Health effects	Environmental effects
Mercury	Primary alkaline batteries, Zinc-carbon batteries Mercuric oxide batteries Silver oxide batteries	▪ Affects human brain, central nervous system,kidneys and liver. ▪ Causes skin sensation such as burning, prickling,itching, or tingling. ▪ Affects genetic and reproductive processes ▪ High mercury exposure causes vision, speech and hearing impairment and may even lead to death.	▪ Marine invertebrates accumulate higherquantities of mercury than aquatic plants. ▪ Mercury bio-accumulates in the food chain ▪ Methyl mercury is the leading mercurycontaminant in fish. ▪ Mercury poisoning in bird's feathers halts the growth of eggs and causes them not to hatch.
Cadmium	Nickel-cadmium batteries	▪ Carcinogenic, damage to livers and kidneys, chronic obstructive pulmonary diseases, cardiovascular and skeletal disorders. ▪ May cause lung cancer and kidney stones. ▪ Kidney damage may lead to an excess	▪ Kidneys of animals are more adversely affected by cadmium poisoning than livers, while their tissues absorb very little cadmium. ▪ Soil contaminated with cadmium is difficult to clean. ▪ Easily taken up by plant roots and accumulates in fruits, vegetables and

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		of urea in the blood accompanied by headache, nausea, coma or even death. ▪ Symptoms of weakness, fever, headache, chills, sweating and muscular pain. ▪ Causes bone diseases: osteomalacia and osteoporosis.	grass.
Lead	Lead-acid batteries Zinc-carbon batteries	▪ Carcinogenic, damage to brain, kidney and liver. ▪ Behavioural disorders and increased blood pressure. ▪ Mental impairment like loss of attention, short term memory, visuospatial capabilities and speaking skills. ▪ Adverse effect on male fertility in case of longexposure. ▪ Spontaneous abortion and premature birth of children in pregnant women. ▪ Kidney damage: reversible proximal tubular damage and reduced glomerular filtration. ▪ Higher exposure may cause irritability, headaches and hallucinations and may advance to convulsions, paralysis and death. ▪ High exposure may cause cere bro vascular disease, heart failure, electrocardiographic abnormalities, impaired liver function, impaired thyroid function and intestinal colic.	▪ Contacts with strong acid or base or presence of nascent hydrogen may generate highly toxicarsine gas. ▪ High dose of lead causes to develop tumour inkidneys of test animals. ▪ Exposure to lead oxide with benzo(a)pyreneleads to lung tumours. ▪ Lead subacetate contamination causes lung adenomas and cerebral gliomas.

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Nickel	Nickel-cadmium batteries Nickel-iron batteries Nickel-zinc batteries	▪ Nickel carbonyl is responsible for lung and nasal cancer. ▪ Skin disorders like itching and burning sensations and the skin tends to become dry and scaly. ▪ Nickel-contaminated water causes kidney damage such as proteinuria (protein in the urine). ▪ Immunological problems: reduced resistance to viral and infectious agents.	▪ Nickel exposure causes deficiency of green pigment in plants and has effects similar to iron-deficiency in humans. ▪ Colloidal nickel has adverse effects on test animals.
Zinc	Zinc-air batteries Zinc-carbon batteries Zinc-chloride batteries	▪ Fumes are toxic when inhaled. ▪ May cause dehydration, electrolyte imbalance, abdominal pain, nausea, vomiting, lethargy, dizziness and muscular in coordination. ▪ May cause kidney failure. ▪ Anaemia and gastrointestinal bleedings in patients. ▪ Extreme intake is believed to cause cancer in humans.	▪ May cause stunted growth, anaemia, reduction in activity of liver catalase and cytochrome oxidase and a decrease in reproduction. ▪ Intratesticular administration of zinc chloride causes carcinogenic effects on test animals.
Potassium hydroxide	Primary alkaline batteries Mercuric oxide batteries Nickel-cadmium batteries	▪ Skin contact may cause blisters, burns, severe irritation, severe pain and/or permanent scars. ▪ Contact with eyes can lead to swelling, impaired vision and/or eventually blindness. ▪ Ingestion may cause burns, diarrhoea, vomiting, severe stomach pain, shock and/or death. .	▪ Reacts violently with strong acids such as hydrochloric acid, sulphuric acid and nitric acid. ▪ Corrosive in moist air to metals such as aluminium, zinc, tin and lead and forms flammable and explosive hydrogen gas. ▪ Attacks some forms of plastics, rubber and coatings.

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Sulphuric acid	Lead-acid batteries	▪ Contact can lead to irritation or burns, or irritation to the mucous membranes of the eyes and the upper respiratory system. ▪ Strong inorganic acid mist containing sulphuric acid is carcinogenic to humans.	▪ Contact with combustibles and organic materials may cause fire and explosion. ▪ Reacts violently with strong agents, metals, strong oxidizers and water. ▪ Contact with metals may produce toxic sulphur dioxide fumes and may release flammable hydrogen gas. ▪ Excessive overcharging or fire may create carbon monoxide, sulphur dioxide, sulphur trioxide, sulphuric acid mist and hydrogen.
Lithium	Lithium-ion batteries Lithium polymer batteries	▪ Causes major disturbance in water balance in body. ▪ Can block synthesis of thyroid hormone. ▪ Causes drowsiness, speech disorder, tremors, unsteady gait, muscle twitching, increased muscle tone, sweating and fever. ▪ Affected children might suffer from weight gain, vomiting, headache, nausea and tremors. ▪ May cause both acute and chronic kidney failure. ▪ Lithium-infected infants may experience shallow breathing, hypotonia, lethargy, cyanosis and bradycardia.	▪ Interferences in carbohydrate metabolism and changes in growth and pituitary hormone of rodents. ▪ Physiological and immunological irregularities leading to infectious diseases. ▪ Birth defects like cleft palates, skeletal anomalies and exencephaly. ▪ Stunted brain growth in test animals.
Manganese	Lithium-manganese dioxide batteries Lithium ion-	▪ Causes cough, abdominal pain and nausea on exposure. ▪ Responsible for neuropsychiatric disorder called ‘manganese madness’ or ‘Parkinson-like’ disease.	▪ Combustible, fine dispersed particles form explosive mixtures in air. ▪ Affects the immune system of marine invertebrates. ▪ Can induce iron deficiency in some

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	manganese oxide batteries Alkaline manganese batteries		algae leading to inhibition of chlorophyll synthesis ▪ Causes disorders in some crops, such as crinkle leaf in cotton and stem streak necrosis in potato.
Potassium	Potassium ion batteries	▪ Eye contact results in redness, watering, itching and corneal damage or blindness. ▪ Skin contact produces inflammation, itching, scaling, reddening and blistering. ▪ Inhalation causes irritation to gastrointestinal or respiratory tract characterized by burning, sneezing and coughing. Over-exposure causes lung damage, choking, unconsciousness or death. ▪ May be toxic to blood, lungs and upper respiratory tract.	▪ Highly flammable in presence of moisture, open flames and heat sparks. ▪ Fire will produce irritating, corrosive and/or toxic gases.

Source;- (Kuchhal & Sharma, 2019).

To solve the problem of effective battery waste management central government come out with new rule Battery waste management rules 2022 as it amend the old rule to cater the need of current time and to promote sustainable development.

Battery waste management rules 2022

The growing prevalence of electric vehicles in India has resulted in a significant demand for battery recycling, as a considerable proportion of used batteries frequently end up in trash disposal systems. The Batteries (Management and Handling) Rules, 2001 ("Old Rules") formerly regulated the procedures for the disposal and management of batteries in India. The regulations primarily targeted the oversight of the gathering and reprocessing of utilised lead acid batteries, with the objective of mitigating the ecological harm resulting from their disposal.

Prior to the current legislation, users were required to return used batteries, while manufacturers, assemblers, importers, and re-conditioners had the responsibility to collect and transport these batteries to registered recyclers. Nevertheless, these laws were limited in scope and did not encompass batteries other than lead-acid batteries, such as lithium-ion batteries commonly found in electric vehicles. Therefore, in order to expand the scope and significance of the current legislation and considering critical input from industry stakeholders and experts, the Government of India formally introduced the Battery Waste Management Rules, 2022 ("Rules") on August 22, 2022. The current regulations now include a wide range of batteries, such as Electric Vehicle batteries, Portable batteries, Automotive batteries, and Industrial batteries. This essay aims to examine the newly established system and its key features, while highlighting the responsibilities and obligations of various stakeholders in the sector..(*New Rules For Management Of Battery Waste*, n.d.)

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Increased scope and applicability

The earlier laws exclusively targeted lead acid batteries, which relied on lead metal for electrical energy. Nevertheless, these restrictions proved insufficient in meeting the requirements of the automotive industry in its present stage of advancement. The scope of the Rules has been expanded to cover all types of batteries, including electric vehicle batteries, portable batteries, automotive batteries, and industrial batteries, irrespective of their shape, size, weight, material composition, and intended use. Moreover, the Rules are expanded to include organisations involved in the collection, sorting, transportation, restoration, and recycling of waste batteries.(*New Rules For Management Of Battery Waste*, n.d.) , In addition, the Old Rules already included producers, consumers, and other relevant stakeholders. Furthermore, the Rules have integrated novel ideas such as Extended Producer Responsibility (EPR), environmental compensation, and a centralised website.(*New Rules For Management Of Battery Waste*, n.d.)

Various stakeholders

The Rules apply to the responsibilities and requirements of various industry stakeholders, such as battery makers, sellers, and importers; consumers; public waste management agencies; and firms involved in the collection, sorting, and disposal of spent batteries. The Rules mandate that each of these stakeholders has distinct responsibilities for effective waste management. The following section deals with certain roles and obligations of the various industry stakeholders as prescribed under the Rules:

(a) Producers

The Rules incorporate the Extended Producer Responsibility (EPR) framework, which holds battery producers accountable for collecting, recycling, or refurbishing waste batteries, as well as utilising recovered materials from waste in the production of new batteries. Extended Producer Responsibility (EPR) requires the collection and recycling/refurbishment of all waste batteries, while strictly forbidding their disposal in landfills or by incineration.(*New Rules For Management Of Battery Waste*, n.d.)

Battery manufacturers must achieve the recycling or refurbishment goals outlined in the Regulations. The producers have the option to either meet these targets independently or involve or approve another company to do so. However, the ultimate duty for reaching the targets rests with the producers.

	Type of Battery	**Minimum use of recycled materials in a battery's total dry weight (in percentage)**			
		2027-28	**2028-29**	**2029-30**	**2030-31 onwards**
1	Portable	5	10	15	20
2	Electric Vehicle	5	10	15	20
		2024-25	**2025-26**	**2026-27**	**2027-28 Onwards**
3	Industrial	35	35	40	40
4	Automative	35	35	40	40

Source: (*New Rules For Management Of Battery Waste*, n.d.)

Additionally, the makers are required to ensure the following aspects in regard to the production of batteries :

i. Ensuring the proper handling of batteries and waste batteries to prevent harm to human health and the environment;
ii. Adhering to the minimum requirements for using domestically recycled materials as outlined in the Rules for manufacturing new batteries;
iii. For imported batteries, producers must meet the minimum requirements for domestically recycled materials either by using the specified amount of recycled materials in other industries or by exporting the required quantity of recycled materials.

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iv. Adherence to the necessary labelling regulations specified in the Rules.

The Rules also mandate that the producers must register with the Central Pollution Control Board ("CPCB"), submit an Extended Producer Responsibility (EPR) plan, and file yearly returns with both the CPCB and the applicable State Pollution Control Board ("SPCB"). If there is a failure to meet the EPR aims or responsibilities specified in the Rules, the CPCB has the authority to suspend or cancel the registration and levy environmental compensation.

(b) Consumers

The regulations stipulate that consumers must dispose of waste batteries separately from other waste streams, particularly mixed waste and domestic waste streams. It is also required that waste batteries be disposed of in an environmentally friendly manner by handing them over to an entity involved in the collection, refurbishment, or recycling of batteries.

(c) Public waste management authorities ("PWMA")

The Rules require the PWMAs to transfer the collected waste batteries to the producers, or their authorised representatives, or organisations involved in refurbishing or recycling, in order to repair or recycle those waste batteries.

(d) Re-furbishers and recyclers

Re-furbishers and recyclers must comply with the requirements by registering with the appropriate State Pollution Control Board (SPCB) using the centralised online portal. They have a duty to maintain compliance with regulations set by the CPCB, as well as other relevant laws on waste management, including rules governing the handling of solid waste, hazardous waste, and plastic trash. Furthermore, the Regulations require re-furbishers and recyclers to regularly submit quarterly reports using specified forms.(*New Rules For Management Of Battery Waste*, n.d.) The returns should provide specific information regarding the quantities of refurbished and recycled batteries, as well as the amount of waste batteries received or collected from various producers or entities. Additionally, it should include the quantity of hazardous, solid, plastic, and other wastes generated after the refurbishment or recycling process. Recyclers must adhere to the Rules by achieving a minimum recovery aim of battery material. (*New Rules For Management Of Battery Waste*, n.d.) Such targets differ for different types of batteries, i.e., portable, automotive, industrial, or electric vehicles as shown in chart.

	Type of Battery	**Recovery Target of Year with % terms**		
		2024-2025	**2025-2026**	**2027**
1	Portable	70	80	90
2	Automative	55	60	60
3	Industrial	55	60	60
4	Electric Vehicle	70	80	90

Source: (*New Rules For Management Of Battery Waste*, n.d.)

(e) Pollution control authorities

The CPCB and SPCB inspected, and audited the registered entities. The Rules empower these authorities to:

- establish protocols and guidelines pertaining to the acquisition, retention, conveyance, recycling, and refurbishment of used batteries in a regulated manner;
- grant registrations to diverse stakeholders;
- carry out inspections and periodic assessments to ensure that manufacturers, re-furbishers, and recyclers adhere to the regulations;
- enforce measures in response to non-compliance and violations of obligations as outlined in the Rules, including those pertaining to the EPR.

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The Rules also mandate the CPCB to establish an implementation committee to ensure the Rules are effectively implemented.

Centralised web portal and issuance of EPR Certificates

The Rules will create a systematic and centralised online platform for producers, recyclers, and re-furbishers to register, submit returns, and share EPR certifications. The purpose of this web portal is to serve as a centralised data store for Rules orders and recommendations. The Rules also mandate that the web portal must present the manufacturers' balance Extended Producer Responsibility (EPR) requirements, as well as audits of waste battery re-furbishers and recyclers.

One important responsibility of the CPCB, as outlined in the Rules, is to create EPR certificates using a centralised web platform. These certificates are based on the amounts of recycled or refurbished materials and are then assigned to recyclers or re-furbishers. The recyclers or re-furbishers have the option to trade the Extended Producer Responsibility (EPR) certificate they have been assigned with the producers in return for waste batteries.

Producers are permitted to get EPR certificates from recyclers or re-furbishers in order to fulfil their EPR obligations according to the Rules. These certificates will be automatically deducted from their responsibility, with a priority given to their earlier liability adjustment. As per the Regulations, producers have the option to purchase Extended Producer Responsibility (EPR) certificates to fulfil their EPR obligations for the current year, any outstanding obligations from past years, and 10% of the obligations for the current year. Producers are not allowed to exchange EPR certifications that are utilised to fulfil their EPR obligations.

Environmental Compensation

In accordance with the polluter pays principle, the Rules have implemented a novel notion of environmental compensation and stipulate that a penalty shall be imposed.

(i) for non-compliance with the registration requirement as stipulated in the Rules;
(ii) for intentionally giving false information or deliberately hiding important facts by registered entities;
(iii) for the submission of counterfeit or altered documents by registered businesses;
(iv) for improper management of waste batteries by organisations involved in their collection, sorting, and disposal.

Further, In the event of a rule violation, the CPCB may suspend, revoke, or impose environmental compensation in addition to other sanctions. the regulations grant the SPCB the authority to assess environmental compensation charges on organizations engaged in the recycling, refurbishment, collection, segregation, and treatment of used batteries. Noncompliance with the obligations and responsibilities outlined in the regulation will lead to the imposition of environmental restitution funds to manage uncollected and non-recycled batteries. Furthermore, any violations of the requirements outlined in the aforementioned guidelines would lead to punitive proceedings as specified in section 15 of the Environment (Protection) Act, 1986.

CONCLUSION

Batteries are utilised in a wide range of applications, both in urban and rural settings. These include toys, mobile devices, computers, tablets, portable music systems, electric watches, calculators, flashlights, radios, cameras, implanted medical equipment, power tools, autos, satellites, submarines, and several other devices. On a global scale, billions of metric tonnes of new batteries are purchased and millions of metric tonnes are disposed of. Scientists and educated people study the health and environmental effects of carelessly discarded batteries. Most governments have strict restrictions on spent battery disposal, however law enforcement is negligent and the proletariat is ignorant in developing and undeveloped nations. Over 90% of secondary rechargeable batteries are recycled in affluent nations. Primary non-rechargeable batteries are thrown away in landfills with other home trash. Although primary batteries are non-recyclable and environmentally damaging, their low cost, extended shelf life, lack of maintenance requirements, and safe operation make them difficult to replace. Potential future researchers may discover methods to effectively recycle these batteries. The Rules serve as a clear demonstration of the legal system adapting to the complexities posed by emerging and evolving technology. The implementation of the Rules has created new pathways and entrepreneurial potential for establishing enterprises related to the collecting, recycling/refurbishment, and management of waste batteries. The mandatory requirement to achieve a minimum percentage of material recovery from waste batteries is expected to stimulate technological advancements in this sector, attract investments in the recycling and refurbishment industry, and create

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new business opportunities. On the whole, the implementation of the Rules appears to be a positive step towards promoting technological progress while minimizing harm to the environment. The Rules include provisions for compulsory online registration, regular reporting and auditing, and the establishment of a committee to supervise their implementation. These characteristics are intended to ensure successful adherence. If the Rules are effectively implemented, India has the capacity to emerge as a global frontrunner in establishing a legal framework for the secure disposal and recycling of batteries.

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