Formal Municipal Solid Waste Management and Its Role In E-Waste Handling a Case Study of Rewa, Madhya Pradesh

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Abstract*—Mid-sized Indian cities face growing pressure to manage increasing volumes of electronic waste (e-waste) within existing municipal solid waste (MSW) systems. Globally, e-waste generation reached 62 million metric tonnes in 2022, of which less than one-quarter was formally documented as recycled. India alone produced over 14 lakh metric tonnes of e-waste in 2025-26, a near-doubling in just eight years. This paper investigates the formal waste management infrastructure in Rewa, Madhya Pradesh, based on field observations and interviews conducted in July 2025 at the Municipal Solid Waste Collection and Transport Hub at PTS Chauraha and the Pahadia Waste-to-Energy plant. The study examines the public-private partnership between Nagar Nigam Rewa and Asia Resil Resustainability Ltd., which operates under a twenty-year contract and processes approximately ninety metric tons of waste daily. Using source-level segregation across forty-five wards with sixty-three compartmentalized vehicles, the system separates dry, wet, hazardous (including e-waste), and sanitary waste. Three transfer hubs each handle up to 150 metric tons daily before final processing at the Pahadia facility, where waste is sorted, recyclables extracted, and non-recyclable materials converted to energy. The paper finds that while the formal system successfully manages mixed MSW and includes e-waste as a hazardous fraction, it lacks dedicated e-waste collection points, specialized dismantling capacity, and public awareness messaging specific to electronics. The paper concludes that the formal infrastructure provides a strong foundation, but without targeted e-waste interventions, most e-waste continues to flow into informal channels. Recommendations include amending the PPP contract to include e-waste performance indicators and establishing a dedicated e-waste drop-off center at existing hubs.

***Index Terms*—Municipal Solid Waste, Public-Private Partnership, Waste-to-Energy, E-waste, Rewa**

I. INTRODUCTION

Electronic waste is one of the fastest-growing components of urban waste streams worldwide. The Global E-waste Monitor 2024, prepared by the United Nations Institute for Training and Research (UNITAR) in partnership with the International Telecommunication Union (ITU), reported that the world generated 62 million metric tonnes of e-waste in 2022an amount that would fill over 1.5 million forty-foot shipping containers. Of this, only 22.3 percent was formally documented as collected and recycled (Forti et al., 2024). The report further projects that global e-waste generation will reach 82 million metric tonnes by 2030 unless urgent policy and infrastructure interventions are implemented. Regional disparities are stark: Europe leads with a formal collection rate of 42.8 percent, while Asia, the largest generator by volume, collects only 11.9 percent of its e-waste through formal channels (Forti et al., 2024).

India mirrors these global trends on a massive scale. The country has emerged as the third-largest generator of e-waste in the world, following only China and the United States. According to data presented to the Indian Parliament by the Ministry of Environment, Forest and Climate Change, India generated over 14.14 lakh metric tonnes (1.414 million metric tonnes) of e-waste in the financial year 2025-26, of which approximately 9.79 lakh metric tonnes (0.979 million metric tonnes) was recycled (Government of India, 2026). This represents a dramatic increase from the 7.08 lakh metric tonnes generated in 2017-18, meaning that India's e-waste generation has nearly doubled in just eight years (Central Pollution Control Board, 2025). The E-Waste (Management) Rules, 2022, which came into effect on April 1, 2023, regulate 106 categories of electrical and electronic equipment, including mobile phones, computers, and uninterruptible power supply systems, and mandate extended producer responsibility (Government of India, 2022). However, despite this regulatory framework, the Central Pollution Control Board estimates that a substantial portion of the country's e-waste continues to be handled by the informal sector, where dismantling and recycling occur without environmental safeguards or worker protection (Central Pollution Control Board, 2025).

For mid-sized cities like Rewa, which lack the dedicated e-waste infrastructure found in metropolitan centers, the challenge is particularly acute. In the formal municipal solid waste system, e-waste is typically treated as a sub-category of hazardous waste rather than as a distinct material stream requiring specialized handling. This paper examines one such system Rewa's twenty-year public-private partnership with Asia Resil Resustainability Ltd. to assess its capacity to manage e-waste and to identify gaps that require policy attention.

II. LITERATURE REVIEW

Scholarly attention to e-waste has grown rapidly over the past decade, reflecting the seriousness of environmental and health crises caused by improper disposal. Widmer and colleagues (2005) provided the first comprehensive framework distinguishing formal and informal recycling systems in developing countries. According to Forti et al. (2024), global e-waste reached 62

million metric tonnes in 2022, of which only 22.3% was formally collected a low rate that underscores the persistent reach of informal channels despite regulatory efforts. In the Indian context, a large gap exists between generation and formal processing. Borthakur and Govind (2018) estimated India's annual e-waste at approximately 2 million tonnes, with less than 5% formally recycled. However, recent CPCB (2025) data reports that out of 1.414 million tonnes generated in 2025-26, about 70% was formally processed. But Kumar and Singh (2021) offer an important caveat: "formal processing" does not always mean environmentally sound recycling; many authorised recyclers still use semi-primitive methods. The informal sector dominates most Indian cities because it offers convenience and competitive prices.

2.1 Public-Private Partnerships (PPPs) in Waste Management

Since the Solid Waste Management Rules, 2016, PPPs have become a key policy instrument in India. A comparative study by Pradhan and Kumar (2023) across six cities found that long-term contracts (15+ years) are associated with better infrastructure and service reliability, but most contracts are limited to mixed municipal waste – no provisions for hazardous fractions like e-waste. This is directly relevant to Rewa, where the 20-year PPP contract between the municipality and Asia Resil contains no e-waste performance indicators. Zurbrugg et al. (2012) studied PPPs in several Asian countries and concluded that successful partnerships require, besides private capital, clear regulatory oversight and community engagement. Without these, PPPs become mere outsourcing arrangements that ignore the waste hierarchy (reduce, reuse, recycle). Singh (2019) analysed the Pimpri-Chinchwad PPP and noted that while the system was financially viable, it failed to integrate historically active informal waste pickers – a finding still relevant to cities like Rewa.

2.2 Formal Versus Informal E-Waste Systems

The coexistence of both systems in the global South is well documented. Sinha-Khetriwal et al. (2020), comparing Switzerland and India, argued that India's informal sector is not merely a problem but a complex economic mechanism that recovers high material value at minimal cost. In Delhi's Seelampur, informal recyclers extract nearly 90% of copper, gold, and silver – albeit at heavy environmental and health cost. Gollakota et al. (2020) found outright bans on informal recycling ineffective and recommended gradual integration through training, certification, and access to formal markets. In the context of repair shops, Lepawsky and McNabb (2010), studying computer repair in Canada and the Philippines, identified component-level reuse as a widespread but under-documented practice. According to Cooper (2015), repair is the most environmentally preferable option in the waste hierarchy because it avoids the energy and material costs of recycling. The systematic reuse of capacitors, ICs, RAM, and batteries observed in Rewa's repair shops aligns with these findings. However, Parajuly and Wenzel (2017) caution that the environmental benefits of reuse depend on safe handling of hazardous components – often absent in informal settings.

2.3 E-Waste Management in Mid-Sized Indian Cities

Most research has focused on metropolitan cities (Delhi, Mumbai, Bengaluru, Chennai); mid-sized cities are neglected. Dwivedy and Mittal (2010) found that in Lucknow (~3 million), most e-waste was either stored at home or sold to itinerant collectors – virtually no formal collection. Jain and Sareen (2021) reported that in Jaipur, repair shops and small scrap dealers handle the majority of e-waste, with plastic components routinely discarded into municipal bins. These findings are fully relevant to Rewa (population 250,000). According to Arora (2020), tier-2 and tier-3 cities face unique governance challenges – they lack the regulatory oversight and infrastructure investment that metros receive. EPR obligations under the E-Waste (Management) Rules, 2022 are often fulfilled through take-back programmes limited to large cities, creating a policy vacuum in mid-sized cities. This vacuum is filled by informal actors, as evidenced in this study by Delhi-based buyers purchasing e-waste from Rewa every 3-6 months.

The literature review above reveals several gaps that this study attempts to fill. First, there is a lack of empirical research on e-waste management in mid-sized Indian cities that have recently adopted formal PPP-based waste systems. Second, existing studies rarely examine the interface between formal MSW infrastructure and informal e-waste handling within the same city; they often treat the two as separate domains. Third, while repair shop practices are occasionally mentioned in e-waste literature, detailed documentation of component-level reuse and pricing structures remains scarce. This study contributes to filling these gaps by providing a grounded, empirical account of Rewa's formal system, its e-waste gaps, and the parallel informal economy. The findings offer a baseline for policy interventions aimed at integrating informal actors into a more sustainable and compliant framework.

III. METHODOLOGY

3.1 Research Approach and Study Design

This study adopted a qualitative and descriptive case study approach to analyze the formal municipal solid waste management system in Rewa (Madhya Pradesh) and the status of e-waste management within it. The case study method is considered suitable for understanding the waste management system operating in real-life conditions, its institutional arrangements, and the interlinkages between formal and informal sectors (Yin, 2018). The objective of the study was to document existing systems, processes, and challenges rather than to test hypotheses.

3.2 Study Area, Site Selection and Sampling

Rewa is a medium-sized city in Madhya Pradesh with a population of approximately 250,000 and 45 municipal corporation wards. The modern solid waste management system operated under a Public-Private Partnership (PPP) between Rewa Municipal Corporation and Asia Resil Recycling & Resiliency Limited, along with a parallel active informal e-waste network, makes this city suitable for the study. The study employed purposive sampling technique. Key formal sites included the municipal solid waste collection and transportation center at P.T.S. Chowk and

the Pahadia waste-to-energy plant. Additionally, to understand the informal flow of e-waste, the scrap center at Dhobia Tanki, electronic repair centers at Shilpi Plaza, computer vendors in the Ramgovind area, Techno Park, and various brand-authorized showrooms were also studied. Information obtained from these sources was used for triangulation of findings.

3.4 Data Collection and Analysis

The field study was conducted in July 2025 over three separate days. Direct observation, semi-structured interviews, and photographic documentation were used for data collection. A detailed observation of waste collection, segregation, storage, and transportation processes was carried out at the P.T.S. Chowk center. A key interview was conducted with Mr. Mukesh Pratap Singh, the center's operations in-charge, obtaining information related to the collection system, vehicle capacity, e-waste management, public awareness activities, and the PPP model. Informal discussions were also held with other staff members as needed. Photography of the site was conducted after obtaining permission. Qualitative data were analyzed using thematic analysis. Information obtained from observation notes and interviews was coded and classified under major themes such as segregation arrangements, hazardous waste management, e-waste management, staff training, and public awareness programs. Quantitative information, such as number of vehicles, waste processing capacity, and daily waste quantity, was compiled from municipal corporation records and operational reports.

3.6 Ethical Considerations and Limitations of the Study

During the study, all participants were informed about the purpose of the research and their voluntary participation, and verbal consent was obtained. Photography was done with prior permission, and no personal information of any employee or citizen was collected. No experimental intervention was conducted in the study. The study had certain limitations. Direct access to the final processing area of the Pahadia waste-to-energy plant was not available. Due to the unavailability of separate records related to e-waste quantity, some data were based on informants' estimates. The absence of household-level surveys meant that a comparative assessment of e-waste flowing through formal and informal channels could not be made. Additionally, the study is based on field observations of limited duration. Despite these limitations, this research presents a systematic empirical analysis of the formal and informal arrangements for e-waste management in Rewa.

IV. RESULTS

4.1 Collection Infrastructure and Source Segregation

Rewa deploys sixty-three garbage collection vehicles, each with four compartments and a total capacity of one metric ton. The compartments are designated as follows: dry waste (paper, plastic, recyclables), wet waste (biodegradable kitchen waste), hazardous waste (including e-waste and biomedical waste), and sanitary waste (compostable materials). Collection occurs

door-to-door across all forty-five wards. According to Mr. Mukesh Pratap Singh, this source-level segregation is critical for downstream processing. Residents are instructed to place e-waste items such as old mobile phones, chargers, wires, and small electronics into the hazardous waste compartment. Larger e-waste items (televisions, computers, refrigerators) are collected separately through bulk waste pick-up on request, though the operator noted that such requests are rare.

4.2 Secondary Storage Hubs

Collected waste is transported to three secondary storage and sorting hubs like PTS Chauraha, Saman Naka, and Manas Bhawan. Each hub has a designed handling capacity of approximately 150 metric tons daily. These hubs act as temporary transfer stations where waste is unloaded, visually inspected for gross contamination, and then reloaded for transport to the central processing facility. At the hubs, hazardous waste including e-waste is stored separately in labelled bins. The hubs also serve as sites for public awareness activities. Under the Information, Education, and Communication (IEC) Campaign, staff conducts door-to-door campaigns, community workshops, and distribute leaflets. However, the campaign focuses primarily on general waste segregation; e-waste is mentioned only briefly as part of hazardous waste.

4.3 Final Processing at Pahadia Waste-to-Energy Plant

All waste from the three hubs is transported to the central facility at Pahadia. Here, waste undergoes scientific segregation recyclable materials (paper, plastics, and metals) are extracted; non-recyclable, non-hazardous waste is processed for energy recovery through combustion; and hazardous waste, including e-waste, is stored temporarily before being sent to authorized recyclers outside the city. The plant plays a key role in managing toxic e-waste components such as wires, motherboards, and medical electronic devices. According to operational staff, these materials are not incinerated at Pahadia but are packed into containers and shipped to facilities in Indore or Delhi that hold authorization under the E-Waste (Management) Rules, 2022. No documentation on the exact quantity of e-waste processed or the identity of receiving recyclers was available at the time of visit.

4.4 Capacity and Institutional Framework

The entire system operates under a twenty-year public-private partnership contract signed in 2020. Daily throughput is approximately ninety metric tons of mixed waste, of which e-waste constitutes a very small fraction estimated by the operator at less than one percent by weight, though no separate weighment is performed. The long-term contract provides financial predictability and has enabled investments in vehicle fleet, hub infrastructure, and the waste-to-energy plant. The success of this model has influenced neighboring cities such as Satna to adopt similar arrangements.

4.5 Identified Gaps in E-Waste Handling

Despite the system's strengths, several gaps specific to e-waste were identified. First, there is no dedicated e-waste collection point in the city; residents who wish to dispose of e-waste separately from household collection have no designated location. Second, the hazardous waste compartment on collection vehicles is small (approximately 250 litres per vehicle), and e-waste often competes for space with biomedical and other hazardous items. Third, hub staff have received no specialized training in e-waste identification or safe handling. Fourth, the IEC campaign does not include e-waste-specific messaging, such as the hazards of open burning of wires or the value of component reuse. Fifth, the PPP contract contains no performance indicators related to e-waste collection volumes or diversion rates.

V. DISCUSSION

Rewa's formal municipal solid waste system represents a substantial improvement over the previously unsegregated collection and open dumping practices that were common in many Indian tier-2 cities until the last decade. The source-level segregation model, the deployment of sixty-three compartmentalised collection vehicles, the three-hub transfer network, and the waste-to-energy plant at Pahadia are technically sound interventions that have tangibly improved urban hygiene and reduced uncontrolled landfilling. In this respect, Rewa's public-private partnership with Asia Resil Resustainability Ltd. aligns with findings from other Indian cities where long-term PPP contracts have led to better infrastructure investment and service reliability (Pradhan & Kumar, 2023). However, the system treats e-waste as a minor sub-category of hazardous waste, an approach that is increasingly untenable given the exponential growth of electronics consumption and the well-documented toxicity of e-waste components such as lead, cadmium, brominated flame retardants, and mercury (Gollakota, Gautam, & Shu, 2020). The scale of the e-waste challenge globally and nationally underscores the urgency of addressing these gaps. With global e-waste generation projected to reach 82 million metric tonnes by 2030 (Forti et al., 2024), even incremental improvements in collection and recycling rates can yield substantial environmental and public health benefits. India's own trajectory—from 7.08 lakh metric tonnes in 2017-18 to 14.14 lakh metric tonnes in 2025-26 (Central Pollution Control Board, 2025; Government of India, 2026)—demonstrates that e-waste is growing at a rate that outstrips the expansion of formal recycling infrastructure. In this context, the absence of a dedicated e-waste collection point in Rewa is not a minor oversight but a structural flaw. Residents who are motivated to dispose of e-waste responsibly have no convenient, trusted option. Consequently, as the fieldwork with Mr. Nannu Kabadi confirmed, most e-waste is sold to itinerant scrap collectors or remains stored in homes, eventually entering unregulated informal channels.

A less visible but equally concerning consequence is the risk of mis-sorting at the hub level. The lack of specialised training for hub staff increases the probability that e-waste items may be inadvertently placed into dry or wet waste fractions. If such items reach the incinerator, they can

release toxic gases and heavy metals into the atmosphere; if they reach the landfill, hazardous substances can leach into soil and groundwater (Kumar & Singh, 2021). This risk is amplified by the small capacity of the hazardous waste compartment (approximately 250 litres per vehicle), which forces crew members to make rapid sorting decisions under space constraints. No formal protocol or visual guide for identifying common e-waste items was observed at the PTS Chauraha hub, a gap that could be addressed with low-cost interventions such as laminated identification charts and brief daily briefings.

The twenty-year PPP contract, while a source of long-term stability, also embeds certain path dependencies. The contract was designed around mixed municipal solid waste metrics—tonnage collected, transport efficiency, waste-to-energy output—and does not include any performance indicators related to e-waste. This omission is not unique to Rewa; as Zurbrugg et al. (2012) observed in their study of Asian waste PPPs, contracts rarely incorporate hazardous or electronic waste targets unless mandated by state or national regulations. In Rewa's case, the Madhya Pradesh Pollution Control Board has not issued specific e-waste collection directives for tier-2 cities, leaving the PPP without a regulatory driver. Amending the contract to include e-waste-specific targets—for example, a monthly e-waste collection quota, the establishment of a drop-off centre, or a requirement to integrate registered informal collectors—would be administratively feasible without renegotiating the entire agreement. Precedent exists: India's formal e-waste processing coverage improved from approximately 10 percent in 2016-17 to about 70 percent in 2024-25 (Central Pollution Control Board, 2025) precisely because policy focus and resources were applied. A similar focus at the city level could yield rapid progress.

It is important to acknowledge that the formal system's current limitations are not solely a matter of technological or contractual design; they also reflect a broader governance challenge. In many mid-sized Indian cities, e-waste falls into a regulatory gap between municipal solid waste rules (which focus on mixed waste) and hazardous waste rules (which focus on industrial effluents). The E-Waste (Management) Rules, 2022, mandate extended producer responsibility, but in practice manufacturers often concentrate their collection efforts in metropolitan areas where volumes are higher and logistics cheaper (Arora, 2020). Rewa, like dozens of other tier-2 cities, remains underserved by producer responsibility organisations. This structural asymmetry means that even if Rewa's PPP were to establish a dedicated e-waste collection point, there may be no authorised recycler within economical transport distance, unless the city aggregates e-waste in sufficient volumes to attract certified recyclers from Indore or Delhi.

Nevertheless, the field observations also revealed a latent opportunity. The presence of active repair shops and scrap dealers demonstrates that there is already a functioning reverse logistics network for e-waste in Rewa, albeit an unregulated one. Rather than viewing this network as a competitor or a problem, the formal system could treat it as a partner. Integration strategies—such as registering scrap dealers as "urban e-waste collection points", providing them with basic safety training and bins, and offering a small fee for e-waste delivered to the Pahadia plant—would cost far less than building a parallel formal network from scratch. International experiences from Germany's dual system and Japan's retailer take-back laws suggest that hybrid

models, where informal collectors are certified and linked to formal recyclers, can achieve collection rates above 40 percent within a few years (Yoshida, Terazono, Ballesteros, & Pham, 2021). For Rewa, such a hybrid approach would not only reduce environmental hazards but also formalise the livelihoods of dozens of small-scale waste workers, an outcome consistent with the just transition principles increasingly emphasised in Indian environmental policy.

In summary, Rewa's formal MSW system is a success story for mixed waste management, but its e-waste handling remains an unresolved weakness. The gaps identified—absence of a dedicated collection point, insufficient training, inadequate contract indicators—are not insurmountable. What is required is a deliberate policy shift that acknowledges e-waste as a distinct material stream, leverages the existing informal network, and uses the twenty-year PPP contract as an instrument for continuous improvement rather than a static arrangement. Without such a shift, the formal system will continue to capture only a small fraction of the city's rapidly growing e-waste, and the environmental and health costs will continue to be externalised to the informal sector and the broader community.

VI. CONCLUSION

This study finds that Rewa's formal municipal solid waste system, developed under a twenty-year public-private partnership, provides a robust infrastructure for mixed waste management and includes e-waste as a hazardous fraction. However, the system lacks dedicated e-waste collection points, specialized training, public awareness messaging on electronics disposal, and contract performance indicators for e-waste. These gaps mean that the formal system captures only a small fraction of the city's e-waste, leaving the majority to be handled by informal actors. The paper concludes that the existing infrastructure is a strong foundation, but targeted interventions are required to make it effective for e-waste, particularly in light of the rapidly growing national and global e-waste burden.

VII. RECOMMENDATIONS

Based on the findings, the following recommendations are made to Nagar Nigam Rewa and Asia Resil Resustainability Ltd. A dedicated e-waste drop-off center should be established at one of the existing transfer hubs, preferably PTS Chauraha due to its central location. The center should accept all categories of e-waste from households free of charge and should operate during extended hours, including weekends. The hazardous waste compartment on collection vehicles should be enlarged or a separate e-waste collection bin should be added. An alternative is to deploy a dedicated e-waste collection vehicle that visits each ward once a month on a published schedule.

All hub staff and collection vehicle crew should receive a half-day training on e-waste identification, safe handling, and storage. The training should be repeated annually and documented. The IEC campaign should be expanded to include e-waste-specific modules. These

should explain what e-waste is, why it is hazardous, the value of component reuse, and the location and hours of the new drop-off center. Door-to-door campaigns should specifically ask residents about old electronics stored at home. The twenty-year PPP contract should be amended to include e-waste performance indicators, such as kilograms of e-waste collected per month, number of drop-off center users, and percentage of plastic e-waste components diverted from municipal garbage.

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