

Trend Analysis of E-Waste Load and Disposal Pattern Assessment in Association with Public Awareness Model in West Bengal, India

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Abstract: This study examines household-level e-waste generation and management practices in West Bengal, India, based on a primary survey of 145 households conducted through Google Forms. The trend analysis of secondary data reveals that while India's total e-waste generation peaked at 1,751,236 tons in 2023–24, the formal processing rate has improved significantly, rising from 26.33% in 2020–21 to over 82.91% by 2024–25. In West Bengal, the primary e-waste load consists of rapidly replaced small devices such as mobile phones, chargers, cables, and lighting equipment. The findings reveal a "hibernation" trend where households store obsolete electronic devices for extended periods due to perceived future utility or lack of accessible disposal options. Despite a relatively high level of awareness regarding environmental risks, disposal practices are dominated by informal recycling channels, such as kabadiwalas, driven by ease of access and economic incentives. The study identifies a critical behavioural gap between awareness and actual formal disposal. To bridge this, a conceptual behavioural model is proposed, emphasizing the need for improved infrastructure, effective implementation of Extended Producer Responsibility (EPR), and the formal integration of informal actors to ensure a sustainable e-waste management system in West Bengal.

Keywords: E-Waste; Informal Recycling; Storage Behaviour; Sustainable Waste Management.

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I. INTRODUCTION

Electronic waste (e-waste) has emerged as one of the fastest-growing waste streams globally, posing significant environmental and public health challenges (Forti et al., 2020). In India, rapid urbanization, digital expansion, and increased consumption of electronic goods have intensified the generation of e-waste, particularly at the household level (CPCB, 2021). Within this national context, West Bengal represents a critical hotspot of e-waste generation, driven by high population density, expanding urban centres, and rising penetration of consumer electronics. According to the Central Pollution Control Board (CPCB), the state generates approximately 41,000–42,000 tonnes of e-waste annually, with a substantial share originating from urban and semi-urban households. A key yet underexplored issue in the region is the accumulation of residential e-waste load, which includes both actively used and obsolete electronic devices retained within households. In many cases, consumers in West Bengal tend to store outdated or non-functional

electronics due to perceived future utility, emotional attachment, or lack of accessible disposal options. This leads to the phenomenon of "hidden e-waste," delaying entry into formal recycling streams and increasing environmental risks (Baldé et al., 2017). Another significant concern is the dominance of informal recycling channels across the state. In cities and towns of West Bengal, informal collectors and scrap dealers (commonly known as kabadiwalas) play a major role in e-waste collection and processing. However, these actors often rely on environmentally unsafe practices, contributing to pollution and health hazards (Awasthi et al., 2016; Kumar et al., 2017). Despite the presence of regulatory frameworks such as the E-Waste (Management) Rules and Extended Producer Responsibility (EPR), formal recycling systems remain largely inaccessible or underutilized in West Bengal. Previous studies indicate a persistent gap between awareness and actual disposal behaviour, with households continuing to depend on informal channels or long-term storage (CPCB, 2021; Gupta et al., 2019).

In this context, there is a critical need to examine household-level dynamics of e-waste generation in West Bengal, particularly focusing on residential load, storage behaviour, and disposal pathways. However, empirical evidence from the state remains limited. Therefore, the present study aims to assess the residential e-waste load, storage behaviour, and informal recycling channels in West Bengal through a survey-based approach. The study seeks to generate region-specific insights that can support policy interventions, strengthen formal recycling systems, and promote sustainable e-waste management practices in the state.

II. LITERATURE REVIEW

Electronic waste (e-waste) has emerged as one of the fastest-growing waste streams globally due to rapid technological advancement, increasing consumer demand, and reduced product lifecycles. According to the Global E-waste Monitor 2020, global e-waste generation reached 53.6 million metric tonnes in 2019, reflecting a sharp rise driven by increased digitalization and consumption patterns (Forti et al., 2020). E-waste contains both valuable recoverable materials and hazardous substances such as lead, mercury, and cadmium, posing serious environmental and health risks if not managed properly (Kumar et al., 2017). In developing countries like India, the e-waste challenge is further intensified by rapid urbanization, expanding middle-class consumption, and inadequate waste management infrastructure. India is among the top e-waste generating countries globally, with a significant portion of waste being handled outside formal systems (Turaga et al., 2019). Notably, nearly 90–95% of e-waste recycling in India is carried out by the informal sector, often using primitive and environmentally unsafe techniques (Awasthi, 2024). This dominance of informal recycling is largely attributed to the lack of accessible formal collection systems, low public awareness, and economic incentives associated with informal practices (Ilankoon et al., 2022). At the household level, e-waste generation is closely linked to consumer behaviour, device ownership patterns, and technological obsolescence. Recent studies emphasize the concept of “hibernated stock,” where obsolete electronic devices are stored rather than disposed of due to sentimental value, perceived future use, or data security concerns (Parajuly et al., 2017). Such storage behaviour significantly delays the flow of e-waste into recycling streams, thereby reducing resource recovery efficiency and increasing long-term environmental risks. Behavioural models further suggest that socio-economic characteristics, awareness levels, and convenience of disposal options play a crucial role in shaping household e-waste management practices (Islam & Huda, 2021; Aboelmaged, 2020).

In the Indian context, the gap between formal and informal recycling systems remains a critical concern. While formal recycling facilities are technologically advanced and environmentally compliant, their limited reach and accessibility constrain their effectiveness. In contrast, informal actors such as scrap dealers (kabadiwalas) and small-scale dismantlers provide door-to-door collection

services, making them more accessible to households despite their environmentally harmful practices (Kumar et al., 2017; Turaga et al., 2019). At the regional level, West Bengal presents a particularly significant case for examining household e-waste dynamics and informal recycling networks. Urban centres such as Kolkata have emerged as important hubs for e-waste generation and processing, where informal recycling dominates the waste management system. Studies indicate that despite relatively high awareness among consumers regarding the environmental impacts of e-waste, disposal decisions are primarily driven by convenience and economic incentives, leading to a preference for informal channels (Adhikari & Saha Roy, 2024). Furthermore, empirical evidence from West Bengal highlights the environmental consequences of informal e-waste recycling practices. Studies have detected elevated concentrations of hazardous metals such as lead, cadmium, and chromium in soil and water samples near informal recycling sites, indicating severe ecological contamination (Dasgupta et al., 2023). These findings underscore the urgent need for sustainable e-waste management interventions in the region. Recent research in cities like Siliguri further suggests that while awareness of e-waste hazards is gradually increasing, proper disposal practices remain limited due to inadequate infrastructure and weak policy implementation (Bandyopadhyay & Mukherjee, 2025). This reflects a persistent gap between knowledge and actual behaviour, which significantly influences household-level e-waste management. Despite the growing body of literature on e-waste management in India, limited research has comprehensively examined the interrelationship between residential e-waste load, storage behaviour, and recycling pathways, particularly in the context of West Bengal. Most existing studies focus either on generation estimates or environmental impacts, with insufficient attention to behavioural dimensions and household decision-making processes.

Therefore, a clear research gap exists in understanding how socio-economic, technological, and behavioural factors collectively influence e-waste generation, storage, and disposal at the household level in West Bengal. Addressing this gap is essential for designing effective policy interventions and promoting sustainable e-waste management practices. This study aims to bridge this gap by providing a survey-based assessment of residential e-waste load, storage behaviour, and informal recycling channels in West Bengal, thereby contributing to both academic literature and policy discourse. Despite growing research on e-waste, critical gaps persist, particularly in West Bengal. Existing studies emphasize macro-level trends while neglecting household-level dynamics and the role of informal recycling interactions (Kumar et al., 2017; Awasthi, 2024). Moreover, the lack of an integrated framework linking generation, storage, and disposal, along with the gap between awareness and actual behaviour, remains insufficiently explored (Parajuly et al., 2017; Islam & Huda, 2021).

➤ Objectives of the Study

The primary objective of this study is to analyse household-level e-waste generation, storage behaviour, and

disposal practices including formal and informal systems in West Bengal. It also seeks to assess the influence of socio-economic factors and awareness levels on e-waste management behaviour, thereby providing insights for sustainable policy interventions (Kumar et al., 2017; Islam & Huda, 2021).

III. DATA SOURCE AND METHODOLOGY

This study adopts a mixed-method approach by integrating both primary and secondary data sources to examine residential e-waste dynamics in West Bengal, India. Primary data were collected through a structured questionnaire survey conducted via Google Forms, covering 145 households from selected urban and semi-urban areas. A stratified random sampling technique was applied to ensure representation across different socio-economic groups. The survey captured information on household characteristics, electronic device ownership, e-waste generation and storage behaviour, disposal practices, and awareness levels. Secondary data were obtained from reliable sources, including the Central Pollution Control Board (CPCB) official dashboard, West Bengal Pollution Control Board (WBPCB) reports, and relevant policy documents such as the E-Waste (Management) Rules. The collected data were analysed using descriptive statistics and inferential techniques such as correlation and regression to examine relationships between variables and test hypotheses (Kumar et al., 2017; Turaga et al., 2019).

➤ *Study Area:*

West Bengal, a premier state in Eastern India, is geographically positioned between 21°25'N to 27°13'N latitude and 85°50'E to 89°53'E longitude, covering a total area of 88,752 sq. km. Characterized by its strategic location, the state shares international borders with Bangladesh, Nepal, and Bhutan, while its internal boundaries are flanked by five Indian states. With a population of approximately 91.3 million across 23 districts, West Bengal is one of India’s most densely populated regions. The socio-economic landscape is heavily influenced by rapid urbanization and the dominance of the Kolkata Metropolitan Area, which serves as a major hub for consumer electronics consumption. This high digital penetration, coupled with an expanding urban and semi-urban demographic, makes West Bengal a critical hotspot for investigating residential e-waste generation, household storage patterns, and the pervasive influence of informal recycling networks.

IV. RESULT AND DISCUSSION

The analysis of year-wise e-waste generation and processing reveals a clear upward trend in both indicators over the study period on India as evident from table 1. Total e-waste generation increased from 1,346,496 tons in 2020–21 to a peak of 1,751,236 tons in 2023–24, followed by a slight decline in the years 2024–25 and 2025–26. This indicates a general growth trend driven by increased consumption of electronic goods, although short-term fluctuations may occur due to policy or market factors. In contrast, the quantity of processed e-waste shows a more consistent and rapid increase, rising from 354,541 tons in 2020–21 to 1,159,000 tons in 2024–25, before slightly declining in 2025–26. This suggests significant improvement in recycling capacity and formal sector involvement over time.

The linear trend for e-waste generation indicates a relatively weak trend (low slope), suggesting that while generation is increasing, it is not growing as rapidly in later years. On the other hand, the linear trend for processed e-waste is indicating that processing capacity is expanding at a much faster rate compared to generation. Moreover, the gap between generated and processed e-waste has significantly narrowed over time. In 2020–21, only about 26.33% of total e-waste was processed, whereas by 2024–25, the processing rate increased to over 82.91%, highlighting improved efficiency in e-waste management systems. From fig.1 we got the R² values are 0.0018 and 0.8436 respectively for generation and processed thereon. The regression equations are as follows:

$$Y = -3621x + 2000000 \dots\dots\dots (1)$$

$$Y = 149706x + 195974 \dots\dots\dots (2)$$

The negative slope of the E-waste generation indicates its decreasing tendency which is a good symptom to our sustainable environment. Overall, the findings suggest that although e-waste generation remains high, the increasing trend in processing indicates progress toward more sustainable e-waste management. However, the remaining gap still points to the continued presence of informal recycling practices and the need for further policy strengthening and infrastructure development.

Table 1 E-Waste Generated and Processed in India in Different Financial Years

Financial year	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Generation of E-waste in Ton	1346496	1601155	1609117	1751236	1397955	1414645
Processed E-Waste in Ton	354541	527131	539256	760663	1159000	979080
Processed (%)	26.33	32.92	33.51	43.44	82.90	69.21

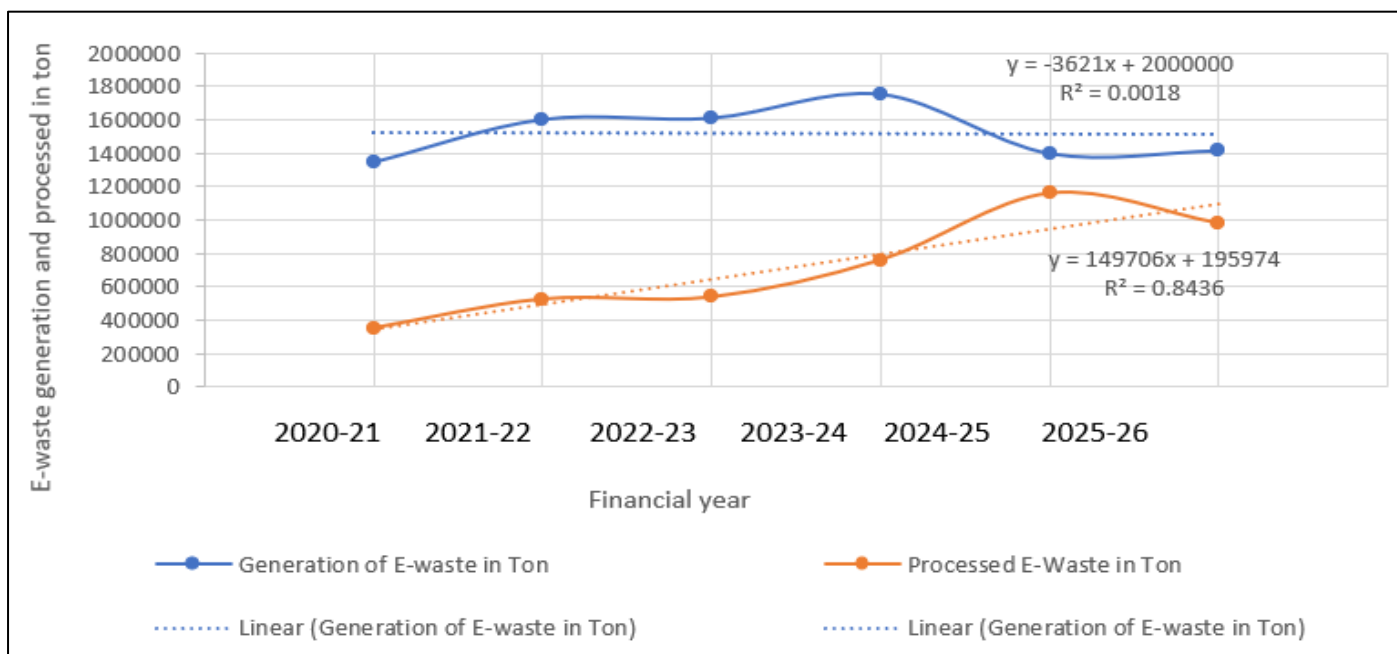


Fig 1 Year-Wise Generation and Processing of E-Waste with Linear Trend Analysis in India

The figure 2 illustrates the composition of e-waste in the study area of West Bengal taken from households of the students of the Neotia University. Analyzing the information received from various mixed urban and semi urban area of West Bengal, it is found that maximum e-waste load consists of mobile phone, chargers and cables, LED lamp, tube light, and fan. On the other hand, items such as CD, calculators, TV, speaker box and computer monitor generate comparatively moderate load and also, DVD, radio, printer and camera generate comparatively lower volumes load. This pattern

indicates that rapidly replaced, small electronic devices and lighting equipment are the primary contributors to household e-waste. The increasing consumption of electronic goods, coupled with shorter product life cycles, has significantly influenced this trend. Similar findings have been reported in studies by Central Pollution Control Board (CPCB, 2020) and United Nations Environment Programme (UNEP, 2019), which highlight that consumer electronics and lighting devices dominate e-waste generation in urban and semi-urban areas.

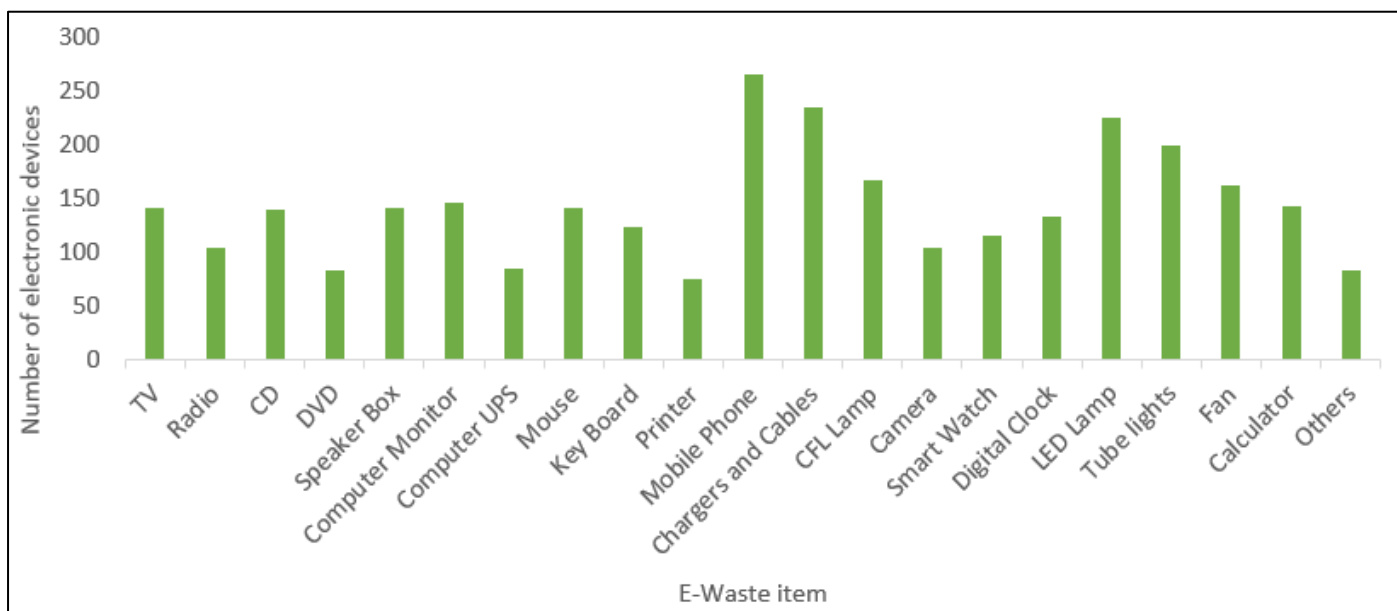


Fig 2 E-Waste Load of the Household

The generation of electronic waste (e-waste) in West Bengal has increased significantly over the past decade, driven by rapid urbanization, technological advancement, and rising consumption of electrical and electronic equipment (EEE). Early estimates indicated that the state generated

approximately 5,872.50 metric tonnes (MT) of e-waste in 2016, primarily from products such as desktop computers, laptops, printers, mobile phones, televisions, and household appliances (WBPCB, 2017). Subsequent projections by the West Bengal Pollution Control Board (WBPCB), in

collaboration with the National Institute of Electronics and Information Technology, suggested a sharp increase in e-waste generation, reaching nearly 144,823 MT by 2019–2020.

At the national level, India has witnessed a rapid surge in e-waste generation, reaching approximately 1.39 million tonnes in 2024–2025 (Central Pollution Control Board, 2024; Press Information Bureau, 2025). Although consistent and updated state-level data for West Bengal remain limited, the state is recognized as a major contributor to the national e-waste stream due to its high population density, expanding urban centers such as Kolkata, and increasing digital penetration.

Furthermore, recent reports indicate a gradual improvement in formal e-waste management infrastructure, with the number of authorized recyclers in West Bengal increasing in recent years (CPCB, 2024). However, despite these developments, a substantial proportion of e-waste continues to be handled by the informal sector, which often employs environmentally unsafe recycling practices (Parajuly et al., 2017; Awasthi et al., 2021). This dual structure of formal and informal systems highlights critical challenges in achieving sustainable e-waste management in

the state. The absence of regularly updated and disaggregated state-level data further constrains effective policy formulation and monitoring. Therefore, strengthening data reporting mechanisms, improving formal recycling capacity, and integrating informal actors into the formal system remain essential for sustainable e-waste governance in West Bengal.

An overall Disposal Pattern of E-Waste in West Bengal is shown in figure 3. The distribution clearly reveals that informal recycling dominates the e-waste management system, accounting for the largest share, while storage and exchange/reuse practices also constitute significant proportions. In contrast, formal recycling contributes only a marginal share, highlighting the limited penetration of authorized recycling facilities. The figure further indicates a persistent reliance on informal channels, driven by factors such as ease of access, economic incentives, and inadequate awareness regarding formal disposal mechanisms. This imbalance between informal and formal systems reflects structural gaps in the existing e-waste management framework. Similar trends have been reported at the national level by Central Pollution Control Board (2024) and in global assessments (Forti et al., 2020), emphasizing the dominance of informal recycling in developing economies.

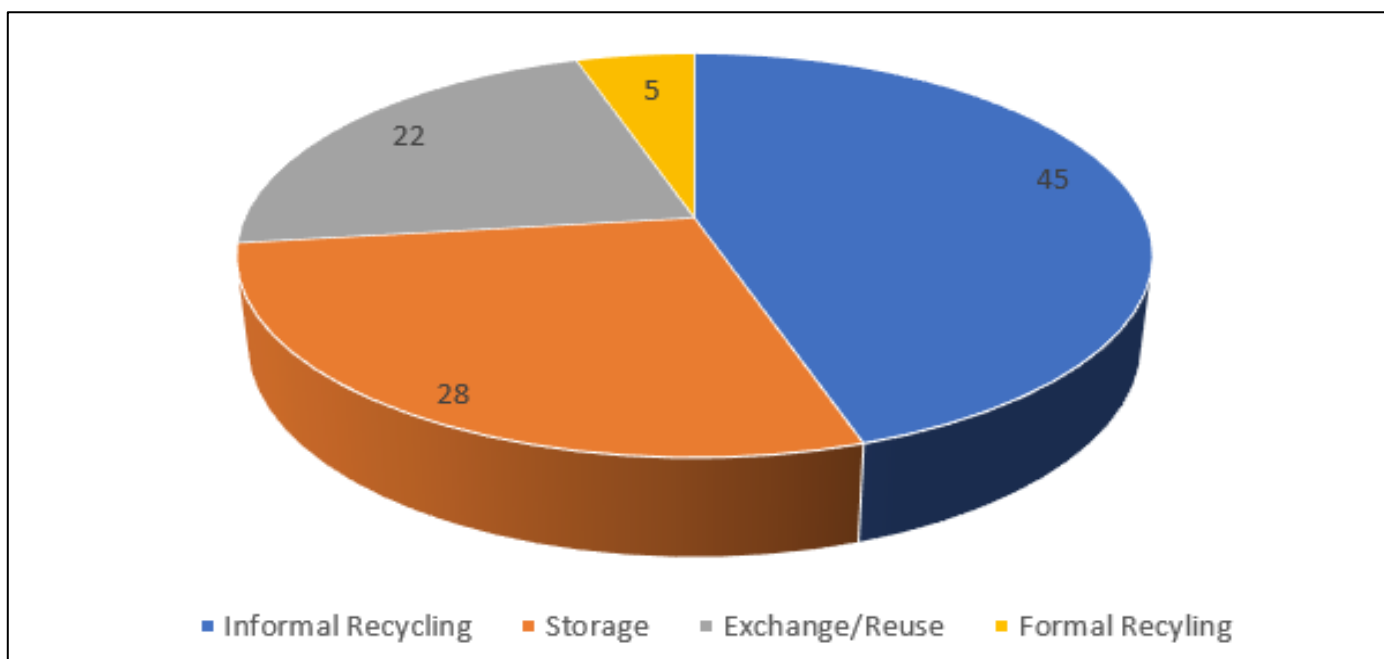


Fig 3 Estimated Disposal Pattern of E-Waste in West Bengal (Based on WBPCB, 2021 and CPCB,2024)

➤ *E-Waste Management Policy and Awareness Framework*

The management of electronic waste (e-waste) in India is primarily governed by the E-Waste (Management) Rules, which emphasize Extended Producer Responsibility (EPR), environmentally sound recycling, and the formalization of the recycling sector. Under these regulations, producers are responsible for the collection and proper disposal of end-of-life electronic products through authorized channels (Ministry of Environment, Forest and Climate Change, 2022).

Regulatory bodies such as the Central Pollution Control Board (CPCB) and State Pollution Control Boards, including the West Bengal Pollution Control Board, play a crucial role in monitoring and implementing e-waste management practices. However, despite the existence of these policy frameworks, a substantial proportion of e-waste continues to be processed by the informal sector, which often lacks environmentally sound technologies and practices (Awasthi et al., 2021; Parajuly et al., 2017).



Fig 4 Behavioural Model of Residential E-Waste Management.

Figure 4 shows the conceptual framework of willingness to manage and pay for e-waste management; this study proposes an integrated policy and awareness framework suitable for West Bengal. The findings highlight that awareness, knowledge, behaviour, and attitude are key determinants influencing households' willingness to manage e-waste. Therefore, an effective policy approach must go beyond regulatory enforcement and focus on strengthening these behavioural components through institutional support and active public engagement.

In this context, several policy measures are essential for ensuring sustainable e-waste management. These include strengthening formal recycling infrastructure and improving its accessibility, ensuring the effective implementation of EPR, and introducing incentive-based mechanisms such as buy-back or exchange schemes to promote formal disposal practices. Furthermore, stricter regulation of informal recycling activities and the gradual integration of informal recyclers into the formal system are necessary to improve both environmental safety and economic inclusiveness. The involvement of local governance institutions in organized waste collection and management systems can further enhance efficiency and accountability.

Simultaneously, awareness-building strategies are critical in influencing responsible behaviour among the public. Awareness campaigns through educational institutions and mass media can significantly enhance public understanding of e-waste hazards and proper disposal practices. Community-based training programs on e-waste segregation, along with the promotion of the 3Rs (Reduce, Reuse, Recycle), can foster sustainable behavioural change. In addition, digital outreach through social media platforms and collaboration with non-governmental organizations (NGOs) can expand the reach and effectiveness of awareness initiatives at the grassroots level.

Overall, the study identifies a significant behavioural gap between awareness and actual disposal practices. This indicates that policy interventions should not only aim to increase awareness but must also focus on transforming behaviour and attitudes to ensure the effective adoption of sustainable e-waste management practices.

V. CONCLUSION

This study highlights a significant upward trend in e-waste generation in India, which reached a peak of approximately 1.75 million tons in the 2023–24 financial year. In West Bengal, this growth is primarily driven by rapid urbanization and the high consumption of small electronic devices, such as mobile phones, chargers, and lighting equipment, which dominate the household e-waste load. While national data indicates a positive shift in formal processing capacity—rising remarkably from 26.33% in 2020–21 to over 82% by 2024–25—local challenges remain. The findings reveal a persistent "hibernation" behaviour among households in West Bengal, where obsolete devices are stored for long periods due to a lack of accessible formal disposal options. Furthermore, despite a general awareness of environmental risks, the disposal pattern is still heavily dominated by the informal sector and scrap dealers, driven by economic incentives and ease of access. To address these challenges, the study proposes an integrated behavioural model that moves beyond simple regulatory enforcement. It is essential to strengthen formal recycling infrastructure and improve its accessibility to bridge the gap between waste generation and formal processing. Policy interventions should focus on the effective implementation of Extended Producer Responsibility (EPR) and the introduction of incentive-based mechanisms, such as buy-back or exchange schemes, to discourage long-term storage. Additionally, the formalization and integration of informal recyclers into the regulated system are crucial to ensure environmental safety and inclusive growth. Ultimately, transforming public attitude through community-based outreach and digital engagement

will be key to fostering sustainable e-waste management practices across West Bengal.

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REFERENCES

- [1]. Aboelmaged, M. (2020). E-waste recycling behaviour: Integration of recycling habits into TPB. *Journal of Cleaner Production*, 278, 124182.
- [2]. Adhikari, K., & Saha Roy, A. (2024). E-waste by mobile phones: Consumer behavior in Kolkata. *Bulletin of Science, Technology & Society*.
- [3]. ASSOCHAM. (2011). *E-waste management in India*. New Delhi.
- [4]. Awasthi, A. K. (2024). Informal sector and e-waste management. *Waste Management & Research*.
- [5]. Awasthi, A. K., Wang, M., Awasthi, M. K., Wang, Z., & Li, J. (2021). Environmental pollution and human body burden from improper recycling of e-waste in China and India. *Environmental Pollution*, 278, 116807.
- [6]. Awasthi, A. K., Zeng, X., & Li, J. (2016). Environmental pollution of electronic waste recycling in India: A critical review. *Environmental Pollution*, 211, 259–270. <https://doi.org/10.1016/j.envpol.2015.11.027>
- [7]. Baldé, C. P., Forti, V., Gray, V., Kuehr, R., & Stegmann, P. (2017). *The Global E-waste Monitor 2017*. United Nations University (UNU), ITU & ISWA.
- [8]. Bandyopadhyay, A., & Mukherjee, A. (2025). Knowledge and practices of e-waste management in Siliguri. *Indian Journal of Community Medicine*.
- [9]. Central Pollution Control Board (CPCB). (2021). *Annual report on e-waste management in India 2020–21*. Ministry of Environment, Forest and Climate Change, Government of India.
- [10]. Central Pollution Control Board (CPCB). (2024). *Annual report on e-waste management in India*. New Delhi.
- [11]. Dasgupta, D., et al. (2023). Environmental impact of informal e-waste recycling. *Environmental Science and Pollution Research*.
- [12]. Forti, V., Baldé, C. P., Kuehr, R., & Bel, G. (2020). *The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential*. United Nations University (UNU), ITU & ISWA.
- [13]. Gupta, N., Yadav, K. K., & Kumar, V. (2019). A review on current status of municipal solid waste management in India. *Journal of Environmental Sciences*, 37, 206–217.
- [14]. Ilankoon, I. M. S. K., et al. (2022). Household e-waste management in India. *Minerals Engineering*, 186, 107722.
- [15]. IMRB. (2007). *E-waste generation in India*. Indian Market Research Bureau.
- [16]. IMRB. (2010). *E-waste assessment in Kolkata Metropolitan Area*.
- [17]. Islam, M. T., & Huda, N. (2021). A global review of consumer behavior towards e-waste. *Journal of Cleaner Production*, 316, 128297.
- [18]. Kumar, A., Holuszko, M., & Espinosa, D. C. R. (2017). E-waste: An overview on generation, collection, legislation and recycling practices. *Resources, Conservation and Recycling*, 122, 32–42. <https://doi.org/10.1016/j.resconrec.2017.01.018>
- [19]. MAIT & GTZ. (2007). *E-waste inventoriatio in India*.
- [20]. Ministry of Environment, Forest and Climate Change. (2022). *E-waste (management) rules*. Government of India.
- [21]. Ministry of Environment and Forests (MoEF). (2008). *Guidelines for environmentally sound management of e-waste*. Government of India.
- [22]. National Institute of Electronics and Information Technology (NIELIT). (2020). *Study on e-waste generation and management in West Bengal*.
- [23]. Parajuly, K., Habib, K., Liu, G., & Wenzel, H. (2017). End-of-life electronic products: Recycling and resource recovery. *Resources, Conservation and Recycling*, 127, 121–135.
- [24]. Parajuly, K., et al. (2017). Future e-waste scenarios and stockpiling behavior. *Resources, Conservation and Recycling*.
- [25]. Press Information Bureau (PIB). (2025). *Government of India reports on e-waste generation and processing*. New Delhi.
- [26]. Rajya Sabha. (2011). *Report on e-waste in India*. Government of India.
- [27]. United Nations Environment Programme (UNEP). (2007). *E-waste management manual*.
- [28]. West Bengal Pollution Control Board (WBPCB). (2017). *Inventory of e-waste generation in West Bengal*. Kolkata.