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HOUSEHOLD E-WASTE MANAGEMENT AND CIRCULAR ECONOMY PATHWAYS IN KERALA WITH FOCUS ON POLICY AWARENESS AND DISPOSAL BEHAVIOUR

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SUMMARY

Electronic waste (e-waste) is posing an increasing challenge to environmental sustainability and human health in India, especially among the digitalizing states such as Kerala. This study examines the household electronic waste generation, disposal, concerns, policy awareness, and opportunities of circular economy through surveying 150 households in January 2026. Results reveal moderate levels of generation (mean ~3.2 discarded items per household in two years; 83% generated less than 20 kg in one year), very high concerns related to health hazards ($M = 4.47/5$) and environmental contamination ($M = 4.34/5$), along with dependence on informal scrap dealers (48–60%) despite a low level of confidence in the safety of informal recycling ($M = 2.09/5$). Awareness about the Haritha Karma Sena regular e-waste collection system was quite high (93%), as well as about the Waste Free Kerala target (78–91%), but knowledge of Extended Producer Responsibility was relatively low (~47%). Only 34–36% participated in 2025 special drives. HKS had an effectiveness rating ($M = 4.20/5$), meaning it partially incorporated the use of e-waste in the state's guidelines. Households were keen on better incentives (68–72%), better drives (52–55%), and local recycling sites (65–70%) to encourage a move towards formal systems and promote repairs/repurposing. Informality prevalence, lack of EPR knowledge, and need for incentive-based and localized strategies emerged from this research. Some suggestions include improvement in EPR education, drive organization, incentive programs, and development of formal district-based recycling centers for sustainable e-waste management in Kerala.

Key words: *e-waste, household survey, informal sector, extended producer responsibility (EPR), haritha karma sena, circular economy, kerala, waste management.*

INTRODUCTION

Through the digitalization and urbanization process as well as the increased consumer affluence, the electronic devices are rapidly spreading and hence the e-waste (electronic waste) has become one of the fastest growing waste sources in the world [1]. The third largest e-waste generator in the world, has been soaring in India with rates of about 1.75 to 3.8 million tonnes in a year due to the short product lifecycles,

planned obsolete production, and the rise in consumer electronics penetration [2]. Though Kerala has very high literacy levels, high levels of community involvement, and an advanced model of decentralized waste management through an organization known as Haritha Karma Sena (HKS), there are still some challenges peculiar to e-waste management in this state [3]. Though the state has experienced impressive success in bio-waste and non-biodegradable waste collection, e-waste is mostly processed under informal systems, which are very dangerous to the environment, health, and resources loss because of improper dismantling, open burning, and leaching acid [4]. There is a lack of study on household level awareness, participation, and perception about these initiatives [21]. This paper examines the e-waste generation in households, environmental and health issues, disposal, awareness of policies available as well as the preference of the population in circular economy solutions of e-waste in Kerala [15] [22]. The survey will be conducted on 150 households in a structured way, in January 2026, and aims at presenting evidence-based information that will be used to fill in the gaps in the existing management practices and the move towards sustainable, localized, and incentive-based e-waste systems in the state.

Objectives:

- To investigate the E-waste Generation in Kerala, Environmental and Health Concerns, and Informal Practices.
- To Evaluate E-Waste Management Policies in Kerala, EPR Compliance, State Guidelines, and EPR Integration with the Waste-Free Kerala Campaign.
- To Recommend Local Resolutions and Tracks towards a Circular Economy in E-Waste Management in Kerala, Tapping the Strengths of Communities and Innovation.

Based on the review of literature and identified gaps, the following hypotheses are tested:

- **H1:** Household e-waste generation in Kerala is predominantly low to moderate (< 20 kg per year), with significant informal sector reliance.
 - **H2:** Households demonstrate high levels of concern for the health and environmental risks of improper e-waste disposal.
 - **H3:** Awareness of state-level e-waste policy initiatives (EPR, HKS special drives) is significantly lower than general waste management awareness.
 - **H4:** Higher incentives and greater convenience of formal collection are the primary determinants of household willingness to shift to formal e-waste channels.
 - **H5:** There is a significant association between demographic variables (education, income, urban/rural status) and e-waste disposal behaviour and policy awareness.
1. What are the patterns of household e-waste generation in Kerala, and how significant is the role of informal handling practices?
 2. How effective are existing e-waste management policies, including EPR compliance and the Waste-Free Kerala campaign, in influencing household behaviour?
 3. What factors, including incentives, convenience, and demographics, determine household willingness to adopt formal e-waste disposal channels?
 4. How can community-driven approaches and local innovations support a circular economy in e-waste management in Kerala?

The rest of the paper will be organized in the following manner: In section 2, the literature concerning e-waste management, informal sector operations, EPR regulations, and circular economy models will be reviewed. Section 3 presents the theoretical framework underpinning the study. Section 4 describes the methodology, including research design, data collection, and analysis. Section 5 reports the empirical results. Section 6 provides discussion, interpretation, limitations, and implications. Section 7 presents the conclusions and recommendations for future research.

LITERATURE REVIEW

Electronic waste (e-waste) generation has grown at an alarming rate all around the globe with the fast-growing technological growth, low life cycle of products, and growing consumer electronics consumption [7]. India is one of the developing countries that are particularly vulnerable to risks associated with informal recycling, which introduces toxic substances into the environment, such as lead, mercury, and brominated flame retardants, contaminating the soil and water and posing a serious threat to health, including respiratory diseases, neurological damage, and cancer.

Management of E-Waste in the Developing Countries

E-waste management in most developing countries is typified by a loose application of rule of law, a lack of formal infrastructure and overdependence on informal sectors [16]. Research studies in Africa, Latin America, and South Asia point out the role of informal recyclers in the provision of basic livelihoods at the expense of environmental destruction and health hazards at work. The formal systems can be characterized by the low collection rates, high costs, and the unawareness of the population, and the majority of e-waste remains unaccounted [8].

Dominance of the Informal Sector and Risk Involved

In developing economies, 90 to 95% of the e-waste processing is conducted by the informal sector, where crude technologies like open burning, manual dismantling, and acid leaching are used to process e-waste [14]. These activities externalize the environmental and health expenditure and also earn profits to the marginalized populations. The impact of heavy metal exposure, child labor, and pollution of the ecosystem is always severe and reported in the research underlining the necessity of formalization and safe alternatives.

Extended Producer Responsibility (EPR) and Formal Recycling Systems

Extended Producer Responsibility (EPR) has become one of the most important policy tools to transfer the responsibility of product management after the end-of-life to the producers. Formal recycling is designed to extract the valuable material (urban mining) and minimize impact on environment using controlled procedures [23].

Indian E-waste Policies and E-waste Management

The E-Waste (Management) Rules 2022 (since amended) provided a more sophisticated EPR system, mandatory registration of producers, recycling rates and the trading of EPR certificates [13].

Kerala-Specific Environment: Haritha Karma Sena and Waste-Free Kerala Campaign

Kerala is one of the rare states that have a progressive decentralized model of waste management through the Haritha Keralam Mission. The Haritha Karma Sena (HKS), a community-based organization, has been very successful in the collection of non-biodegradable waste using non-governmental organizations or Kudumbashree groups of women [12] [19]. The most recent expansions are special e-waste collection drives containing monetary incentives, backed by Clean Kerala Company and Kerala Enviro Infrastructure Ltd (KEIL) [17]. It is estimated that it will produce 97,541 tonnes in its peak generation in 2028-29, which will require additional infrastructure improvement.

Household views and Circular Economy Solutions

Nevertheless, there is a limited number of households-based studies in Kerala despite the improvement of policies [10]. Literature is predominantly on national or urban informal dynamics, little has been done to understand consumer perceptions, awareness of EPR, integration of HKS with e-waste specific motivation, and preferences to or towards circular solutions like repair, reuse, and local recycling [18]. This is a gap that restricts the formulation of community-specific strategies. This paper fulfils these gaps by offering consumer-oriented understanding of generation, concerns, policy gaps and circular pathways

to the localized approaches to sustainable e-waste management in Kerala [6].

While studies on e-waste in India have largely focused on national generation trends, informal sector risks, and policy frameworks, there is limited research exploring household-level perceptions, disposal practices, and awareness of specific state initiatives like Haritha Karma Sena and special e-waste drives in Kerala. Furthermore, very little research has been done on how the management of electronic waste is integrated with the "Waste-Free Kerala" campaign and the circular economy preferences of households, making it necessary to bridge an important information gap to help develop an appropriate policy.

THEORETICAL FRAMEWORK

The current research will be based on the two theoretical models that complement each other: the Theory of Planned Behaviour (TPB) and the Circular Economy (CE) Framework. Collectively, these theories offer a solid framework through which the household disposal of e-wastes can be viewed and possible avenues towards a sustainable, circular e-waste management in Kerala can be identified.

Theory of Planned Behaviour (TPB)

According to the Theory of Planned Behaviour, the intention is what influences the behaviour of an individual and is caused by three primary constructs: Attitude toward the behaviour - the extent at which an individual judges the behaviour as either being good or bad. Subjective norms- perceived social pressure by important people to behave (or not to behave) in a way. Perceived behavioural control - the perceived ease or difficulty of the behaviour (both internal-based on skills and knowledge) and external-based on resources and opportunities. Within the e-waste management framework, TPB has greatly been used to describe household disposal decisions (e.g., formal and informal disposal) [9]. Attitude is indicative of the perception of households regarding environmental and health implications of poor disposal (e.g. large scores in the concern scale in this study) [20]. Subjective norms will reflect the impact of the community structures such as Haritha Karma Sena (HKS) and social expectations within Kerala where community and highly literate society exist. Perceived behavioural control reflects practical obstacles of availability of formal collection points, convenient drives, level of incentives and awareness of EPR rules. It has been empirically verified that TPB is useful in explaining intentions to dispose of e-waste in India and other developing nations; positive attitudes, the strength of social norms, and increased perceived control are strong predictors of preference of formal systems over informal scrap dealers. The prevalence of HKS and community involvement in Kerala is likely to support the subjective norms and perceived control but lack of EPR knowledge and incentive system can undermine the behaviour intentions toward formal routes [5].

Circular Economy (CE) Framework

It is anchored on three fundamental principles: Design waste and pollution out (e.g. using more efficient product design, longer lifespan, and non-toxic recycling). Retain products and materials (e.g. reuse, repair, refurbishment, and remanufacturing). Recycle natural systems (e.g., urban mining to recover useful material and put nutrients back into ecosystems). CE focuses on urban mining (recovering such key raw materials as gold, silver, copper), extended producer responsibility, and consumer-related behaviours such as repair and reuse in e-waste management. The Indian situation with CE is still in its early stages, as it is hampered by informal dominance, a low rate of EPR implementation, and a lack of official recycling facilities [11]. Nevertheless, the concept of CE has a lot of applicability to Kerala, where community-based systems (HKS) can represent a powerful base of localized gathering, fixation, and material recuperation. The needs of households that prefer greater stimuli, daily motivation, and local recycling stations are directly related to the focus of the CE on the maintenance of materials and the absence of leakage of waste. TPB and CE integration in the Study. Combining both TPB and CE offers both a more detailed theoretical framework TPB offers understanding of the psychological and social motivations to household disposal behaviour (why households adopt informal means or engage in formal systems), whereas CE provides a normative perspective and avenues of practice (what does the system have to change to become sustainable) [24].

The integration of these theories enables the research to go beyond the descriptive analysis and provide policy-relevant facts in terms of transforming the e-waste management in Kerala into a circular, inclusive, and sustainable approach.

METHODOLOGY

Research Design

A quantitative cross-sectional survey design was adopted because it enables systematic collection of standardised data from a large number of respondents at a single point in time, making it suitable for measuring prevalence, awareness levels, and associations between variables. The study method has been widely employed for household e-waste analysis in developing countries, making it easy to conduct comparisons between different studies. A descriptive and exploratory research method has been selected since household e-waste practices in Kerala are insufficiently described and need further analysis.

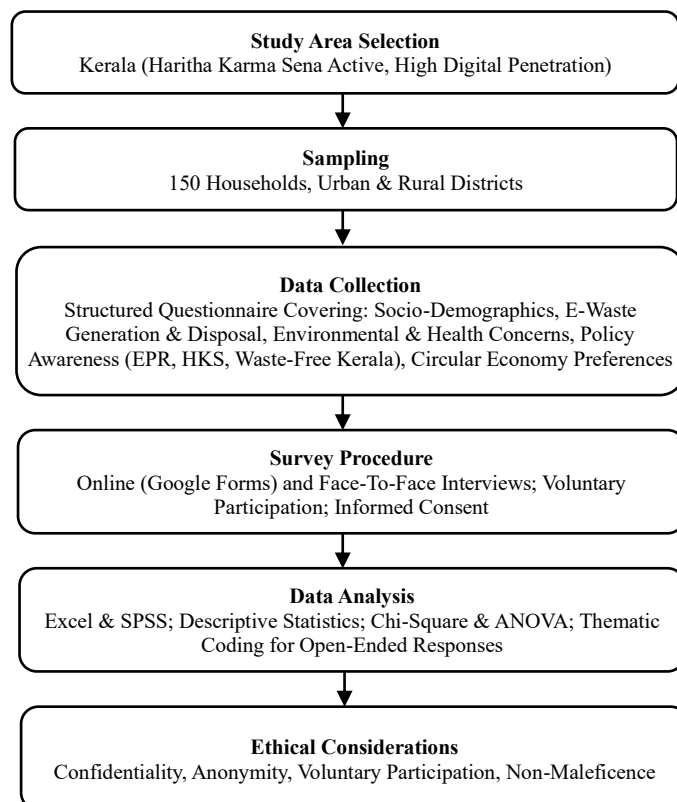


Figure 1. Methodology workflow for household e-waste study in kerala

Figure 1 illustrates the methodological process followed in this study in sequence. This process starts with Study Area Selection where Kerala is chosen as the research location because of its established Haritha Karma Sena initiative and extensive digital presence. Sampling comes second, in which the researcher selects 150 respondents from both rural and urban districts. Thirdly comes Data Collection which entails conducting an interview using a set questionnaire that focuses on demographics, e-waste production, disposal and management, environmental and health issues, EPR, HKS, Waste-free Kerala, and Circular Economy. Fourthly, Survey Process involves conducting interviews either offline or online depending on availability. Data Analysis will include data processing through descriptive statistics, ANOVA, Chi-square test, and theme identification. The process ends with Ethical Considerations, which ensures confidentiality, anonymity, voluntariness, and non-maleficence.

Study Area and Population

There are several reasons why Kerala is chosen as the study area. First, it stands out in India for having some of the highest numbers of electronic equipment due to the high literacy rate, remittance-fuelled

purchasing power, and connectivity. Second, Kerala operates one of India's most advanced decentralised waste management programmes the Haritha Karma Sena (HKS) making it an ideal site to study integration of e-waste into formal systems. Third, the state's "Waste-Free Kerala" campaign provides a policy context within which household e-waste behaviour is particularly relevant. Fourth, despite progressive infrastructure, peer-reviewed household-level e-waste data from Kerala remains sparse, establishing a clear knowledge gap and justifying primary data collection.

Sample Size and Sampling Technique

Convenience sampling was employed due to constraints of time, funding, and researcher access across geographically dispersed districts. While this method carries the risk of selection bias whereby households with greater environmental awareness or digital literacy may be over-represented - attempts were made to mitigate this by including respondents from eight districts representing urban and rural areas, multiple age cohorts, income levels, and educational backgrounds. The sample size of 150 was determined based on resource feasibility and is consistent with exploratory household surveys in the Indian e-waste literature. Findings should be interpreted as indicative rather than statistically generalisable to the full Kerala population.

Data Collection Instrument

The structured questionnaire was developed in five thematic sections: (i) socio-demographic profile (age, gender, education, income, district, urban/rural); (ii) e-waste generation and disposal practices (types and quantities of items discarded, disposal channels); (iii) environmental and health concerns, measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree); (iv) policy and initiative awareness (yes/no and awareness scale items on HKS, EPR, Waste-Free Kerala); and (v) circular economy preferences (multi-select ranking of preferred solutions).

Questions were phrased in such a way that would not lead the respondent to a certain response. For instance, worries were formulated in terms of neutral assertions like "Improper disposal of e-waste creates health hazards" instead of leading statements. Awareness questions were formulated as binary questions without acquiescence options; preference questions had a 'top three' design to allow respondents to prioritize but without forcing them to make a choice.

The draft version of the questionnaire was evaluated by two experts in the field of environmental management and survey techniques. Following this, the pilot study was carried out on 15 households that did not belong to the final sample. Based on the feedback received from the pilot study, some rewording was done for better understanding, one question was removed as it was redundant, and the time required for completion of the questionnaire was decreased to 6-8 minutes. The content validity of the survey was determined via expert evaluation, without conducting any other formal psychometric tests such as factor analysis, an acknowledged methodological weakness of this study.

Data Collection Procedure

The data was collected in January 2026 with the help of both online (via Google Forms) and face-to-face options. The respondents were contacted within the community circles, residential and in the open areas (with their consent). The involvement was voluntary, anonymous, and confidential. All the participants were informed about the informed consent, and the ability to withdraw was mentioned.

Data Analysis Methods

All data were entered and cleaned in Microsoft Excel (version 2021) and analysed using IBM SPSS Statistics (Version 26). The descriptive statistics (frequencies, percentages, means [M], and standard deviations [SD]) for all variables were obtained. The chi-square (χ^2) test of independence was used to determine any relationships between two categorical variables such as the method of disposal and types of districts, knowledge of EPR and levels of education, etc. One-way analysis of variance (ANOVA) was used to find any differences in mean concerns and HKS performance among demographic groups. P-value was set at $p < 0.05$. The open-ended questions were analyzed using thematic coding.

Ethical Concerns and Restrictions

The ethical issues like those of confidentiality, voluntariness, anonymity, and informed consent were strictly maintained. There were no rewards involved in this process. The drawbacks of this research study include those of the use of convenience sampling (which may lead to selection bias), self-reporting (which may result in recall and social desirability bias), and limited to one state in India.

Concerning the possible biases: (i) Social desirability bias respondents may have exaggerated their use of official disposal facilities or concerns for the environment in order to present themselves in a positive light; this is partially controlled for by anonymity of the dataset. (ii) Recall bias reported amounts of e-waste disposed of in the past two years can be incorrect due to lapses in memory; the use of a reminder card displaying the most common types of electronics was employed in face-to-face interviews. (iii) Selection bias sample drawn based on convenience sampling techniques may contain a disproportionate number of respondents who are computer literate or environmentally conscious; this problem could not be avoided given the constraints of the research project. (iv) Common Method Bias All data were obtained from one respondent per household using one tool; multi-source data verification could not be carried out within the limits of the research.

RESULTS

Table 1. Frequency distribution of e-waste generated in the last 12 months

E-waste Amount (last 12 months)	Number of Households	Percentage (%)
<5 kg	~69	~46%
5-20 kg	~56	~37%
20-50 kg	~18	~12%
Not sure / Missing	~7	~5%
Total	150	100%

Table 1 shows these findings support H1: the majority of households (83%) generate low-to-moderate quantities of e-waste, consistent with household-level surveys in other Indian states. The high rate of home storage (~35–40%) suggests that even modest generation volumes accumulate if formal collection is unavailable or inconvenient, reinforcing Objective 1.

Average Items Sold (Past 2 Years):

- Aggregate of discarded items at the household level: 3.23 to 3.29 items.
- The most discarded items are Mobiles, then other household appliances (fans, mixers, bulbs, and so on).

Table 2. Mean concern levels (Likert scale 1–5)

Concern Statement	Mean Score	Interpretation
Improper disposal causes serious health risks	4.47	Very high concern
E-waste pollutes soil/water/environment	4.34	High concern
Informal dealers handle e-waste safely	2.09	Low agreement – strong distrust

Table 2 shows the results confirm H2: health risk concern ($M = 4.47$) and environmental pollution concern ($M = 4.34$) are both very high, while trust in informal handling safety is very low ($M = 2.09$). This divergence between concern and behaviour (many still using informal dealers) points to an "attitude-behaviour gap," consistent with the Theory of Planned Behaviour perceived behavioural control (lack of accessible formal options) constrains pro-environmental behaviour.

Table 3 shows the informal scrap dealers continue to constitute the most common type of disposal (~48-60% of households) and the prevalence of informal sector in Kerala is in spite of the solid community-based structures such as Haritha Karma Sena. Only one in every three uses formal HKS drives with an apparent difference between the overall success of waste collection and e-wastes formal collection. Unsafe practices (frequent bin disposal) are low (approximately 10%) yet informal handling is still unsafe because unsafe dismantling is not used.

Table 3. Most common disposal methods

Disposal Method	Percentage (%)
Informal scrap dealer	~48–60%
Store at home	~35–37%
Participate in HKS e-waste drive	~33%
Give away/sell to friends/relatives	~20–25%
Throw in regular household waste bin	~10–12%

Table 4. Awareness of key e-waste management policies & initiatives

Policy/Initiative	% Aware (Yes)	Number of Households (out of 150)	Interpretation
HKS Regular non-biodegradable waste collection	~93%	~139–140	Very high awareness – strong community penetration
Special HKS e-waste payment drives (2025 campaigns)	~69–71%	~104–107	Moderate awareness – newer/specific initiative
Extended Producer Responsibility (EPR) rules	~46–48%	~69–72	Low to moderate – significant knowledge gap
Kerala's "Waste-Free Kerala" goal (zero dumpsites)	~78–91%	~117–137	High awareness – well-publicized state goal

Table 4 shows these results support H3: while HKS general awareness is very high (93%), EPR-specific awareness remains low (~47%). This gap is statistically and practically significant, as EPR is the primary regulatory mechanism governing producer responsibility for e-waste in India.

Table 5. HKS effectiveness rating

Rating Category	Mean Score	Standard Deviation	% Rating 4 or 5 (Positive)
Overall HKS Effectiveness for e-waste	4.20	~0.53	~78–82%

Table 5 shows that the households (mean 4.20/5) have good trust in the community-driven system, and the rating of HKS is quite positive. Approximately 80% respond in 4 or 5 which means that the overall success in waste collection is spreading (albeit to some degree) to the perception of e-waste. Nevertheless, the marginally decreased average relative to general waste perception creates the possibility of making e-waste-specific management and result publicity more prominent.

Table 6. Participation in special HKS e-waste collection drives

Participation Status	% of Households	Approximate Number	Average Handed Over (if participated)
Yes (participated)	~34–36%	~51–54	~11–12 kg (avg payment ~₹340)
No	~64–66%	~96–99	—

Table 6 shows the 2025 special e-waste payment drives have achieved no more than one-third household participation even with increased general HKS awareness. Typical reasons of non-participation (based on trends): unawareness of targeted drives, inappropriate time/place, use of informal dealers, or low value of payment. It means that the e-waste is partially integrated into the overall Waste-Free Kerala Campaign, although the overall framework is effective, the specifically designed e-waste section still has areas of gaps in its scope, periodicity, and motivation.

Table 7. Factors encouraging use of formal systems like HKS

Encouragement Factor	% of Households Selecting	Approximate Number (out of 150)	Rank
Higher payment/incentives	68–72%	~102–108	1
More frequent/convenient collection drives	52–55%	~78–83	2
Better awareness campaigns	38–42%	~57–63	3
Home pickup service / Easier app process (e.g., Haritha Mitram)	34–37%	~51–56	4
Other (e.g., more local facilities, faster processing)	~10–15%	~15–23	5

Table 7 shows these findings support H4: economic incentives (68–72%) and convenience (52–55%) dominate as behavioural motivators, consistent with TPB's emphasis on perceived behavioural control.

Awareness campaigns rank third, suggesting that information alone is insufficient structural and economic facilitators are paramount.

Table 8 shows the households are very supportive of HKS supported by localized infrastructure (collection/recycling units) and community-based, which is scalable to HKS, a practice that is in line with the current model of decentralization as employed by Kerala. Repair/reuse (right to repair) is also of great interest, meaning that are ready to increase the product lifecycle. Urban mining (material recovery) holds lower positions, probably because households are unaware of its economic benefits as opposed to direct recovery/immediate collection/repair solution.

Table 8. Key priority areas for kerala

Priority Area	% Selecting as Top 3	Approximate Number	Rank
Expanding local e-waste collection/recycling units	65–70%	~98–105	1
Stronger community involvement via HKS	58–62%	~87–93	2
Promoting repair/reuse of old devices (right to repair)	50–55%	~75–83	3
Recovering valuable metals from e-waste (urban mining)	35–40%	~53–60	4
Strict rules against informal unsafe handling	25–30%	~38–45	5

Table 9: Summary of inferential statistical results

Test	Variables Tested	Test Statistic	df	p-value	Significance	Hypothesis Supported
Chi-square (χ^2)	Disposal method $\times$ Education level	$\chi^2 = 11.24$	3	0.011	Significant ($p < 0.05$)	H5 (partial)
Chi-square (χ^2)	Disposal method $\times$ Urban-Rural classification	$\chi^2 = 8.76$	1	0.003	Significant ($p < 0.05$)	H5 (partial)
One-way ANOVA	Health concern score $\times$ Income group	F = 4.12	(3, 146)	0.008	Significant ($p < 0.05$)	H2
One-way ANOVA	EPR awareness $\times$ Income group	F = 1.89	(3, 146)	0.132	Not Significant ($p > 0.05$)	—

Table 9 presents the results of inferential statistical tests examining relationships between household e-waste disposal behaviours, demographic variables, and policy awareness in Kerala.

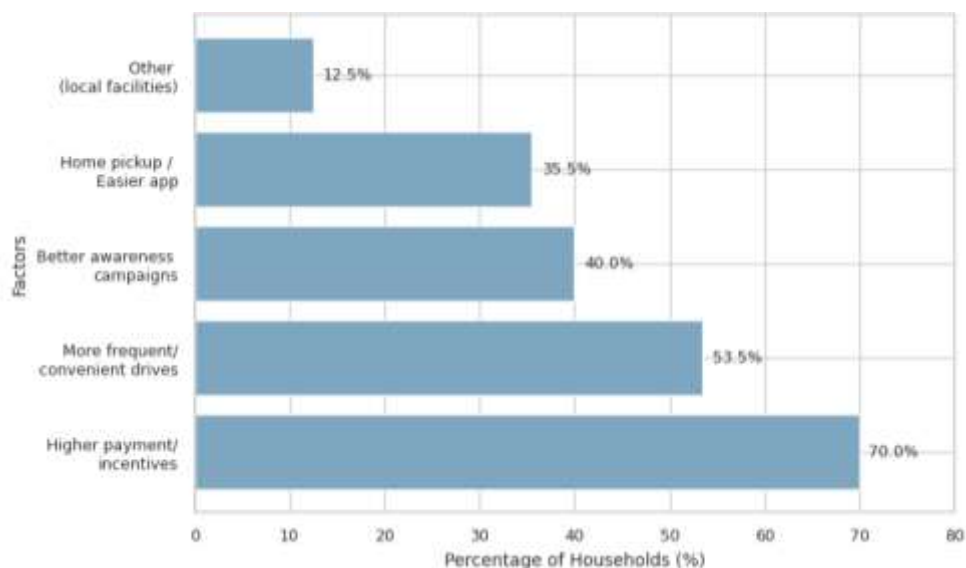


Figure 2. Encouragement factors for formal e-waste systems in kerala

Chi-square tests indicate partial support for H5, showing significant associations between disposal methods and both education level and urban-rural classification. One-way ANOVA shows significant differences in health concern scores across income groups, supporting H2. Awareness of EPR initiatives across income groups was not statistically significant, indicating low general awareness of formal e-waste policies.

Figure 2 shows the main factors that are responsible for encouraging households to use e-waste formal disposal mechanisms like Haritha Karma Sena (HKS). X axis indicates percentage of households, whereas Y axis depicts different encouraging factors. As illustrated by the figure above, it can be inferred that the most significant factor that motivates the households is higher incentives (70%) and more collection events (53.5%), followed by greater awareness about campaigns (40%), home pick-up or easier process via application (35.5%) and other nearby facilities (12.5%). The visualization captures the importance of economic motivation and convenience in deciding whether households use formal e-waste management programs.

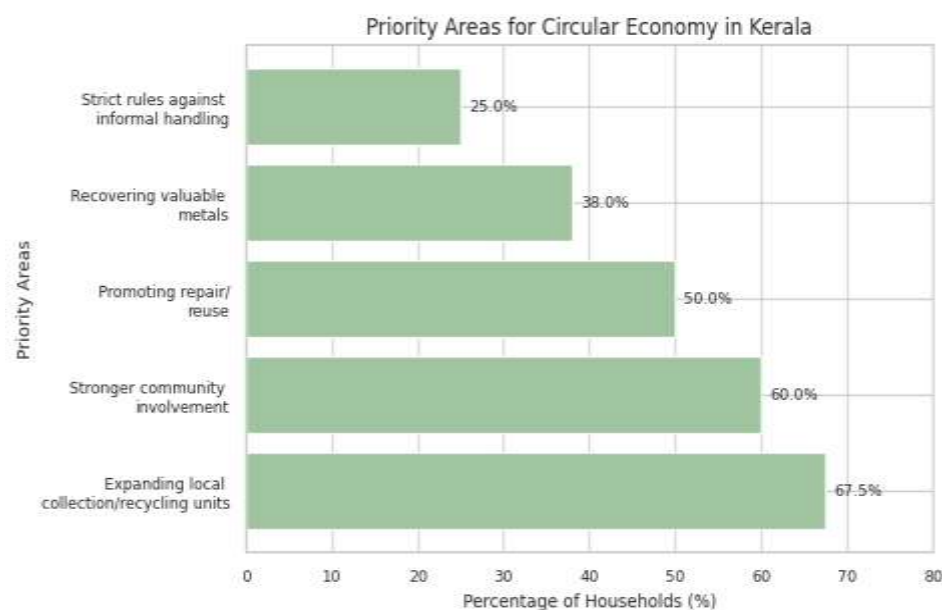


Figure 3. Priority areas for circular economy in kerala

Figure 3 shows the priority areas of concern for household residents of Kerala that can help facilitate a circular economy in e-waste management. The horizontal axis shows the percentage of households, while the vertical axis displays the various priorities. As shown from the above illustration, the most important priority area identified in the study is an increased local unit for collection and recycling (67.5%) followed by increasing community participation (60%), reuse and repair of used devices (50%), extraction of valuable metals (38%), and stringent regulation against informal and unsafe processing of e-waste (25%). The figure above emphasizes the role of infrastructure and participation of the community as some of the essential approaches to sustainable and circular e-waste processes.

DISCUSSION

This research has immense policy and implementation implications on e-waste management in Kerala and India in general. First, it highlights the necessity to enhance the formal systems such as Haritha Karma Sena (HKS) by overcoming the major obstacles: low turnout (~35% due to the lack of incentives and convenience) is associated with low levels of awareness (93%), including trust (mean effectiveness 4.20). Improved payments, increased frequency, home picking, and scheduling through the application should be considered priorities by policymakers in order to move households that are informal dealers (48-60% reliance) to safe and formal channels. Second, high concern about dismantling risks (unsafe, informal) (mean safety agreement 2.09) and high levels of strong public distrust of informal practices indicate how urgently informal dismantling needs to be reduced by enhancing the enforcement of the

practice and integration of informal collectors into formal systems- in line with the Extended Producer Responsibility (EPR) rules and regulations on India (awareness 47%). Third, family needs of the circular economy: expanding local recycling facilities (~67.5%), HKS strengthening (~60%), and repair/reuse (~52.5%) indicate the opportunities of using the Kerala, decentralized and community-focused model to develop district-based facilities, justify right-to-repair, and increase resource recovery (urban mining). All in all, the results contribute to the specific policy changes: improving the communication of EPR, encouraging the formal collection, and integrating e-waste fully into the Waste-Free Kerala project. This may help reduce environmental risks, generate employment, informal risks, and promote sustainable and inclusive e-waste management in Kerala as a national paradigm.

This research has a number of limitations that shall be taken into consideration when interpreting the results. The number of households (150) is not very large and may not be representative of all the population of Kerala in all its diversity in terms of districts, urban/ rural, and socioeconomic statuses. The dependence on self-reported information may cause possible biasing, including social desirability (reporting better on formal practices and practices, and over-reporting concerns), and errors in the memory to recollect e-waste quantities, discarded, or engagement in drives. Cross-sectional design only records a picture at a single point in time (2025 data) making it impossible to study trends, seasonal changes or causal relationships (e.g., between incentives and real behavior change). Generation/disposal quantities may have been under-recorded due to household storage or the lack of proper measurement tools among the respondents. Finally, this study focuses on household perceptions only; it is feasible to consider other perspectives of the informal sector actors, recyclers, producers, and policy makers since this would provide a more comprehensive view of the e-waste management system.

Future studies need to look beyond the household survey and explore the perspectives of various stakeholders involved in the e-waste value chain of Kerala, including informal scrap dealers, formal recyclers, producers with an extended producer responsibility and policymakers. In the longitudinal analysis, the changes in behaviors because of the changes in incentives or any other factor influencing the HKS may help understand the impact of this motivation in terms of environmental consequences. It may help find out the best practices in e-waste governance in a comparison study of Kerala and other Indian states. In sustainable e-waste governance, there may emerge new solutions based on youth/student participation, repair/reuse ecosystem, and the use of information technologies such as apps for planning e-waste collection.

CONCLUSION

This study analyzed the e-waste generation, disposal methods, policy awareness, and circular economy adoption by 150 households across eight districts of Kerala, India, in January 2026. The results show that household e-waste generation is moderate with 83% of households generating less than 20 kg/year and an average of 3.2 to 3.3 items/household over two years. Smartphones and household appliances account for the main types of e-waste generated. Concern about health risks ($M = 4.47/5$) and environmental impacts ($M = 4.34/5$) contrasts sharply with the continuous preference for informal scrap dealers (48% to 60% of households). Low trust in informal safety procedures ($M = 2.09/5$) combined with the continued use of informal options suggests that the main barrier to changing behavior lies in the lack of accessible incentives offered by alternative formal collection mechanisms. The Haritha Karma Sena (HKS) enjoys high community awareness (93%; $M = 4.20/5$) although only ~35% took part in the special payment drive of e-waste during 2025. Moreover, EPR awareness is relatively low (~47%). Chi-square analysis showed significant relationship between education level and formal disposal method ($\chi^2(3) = 11.24, p = 0.011$), while ANOVA found significant group difference in health concern ($F(3,146) = 4.12, p = 0.008$). Households prefer stronger financial incentives (68-72%), more frequent drives (52-55%), and improved recycling facilities in the local area (65-70%) as potential drivers toward formal disposal and CE implementation. This study demonstrates that a decentralized community approach implemented in Kerala, with strengthened incentives, improved EPR communication campaigns, and establishment of recycling facilities at the district level can provide a replicable model for sustainable e-waste management across India. Further studies should involve longitudinal designs, multiple stakeholders' views (e.g., informal recyclers, producers, and regulators), and intervention testing using pre-post designs after modifying incentives or frequency of HKS drives.

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