

A Bibliometric Analysis of Electronic Waste Management: Issues and Challenges

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Abstract

Electronic waste is becoming a burgeoning problem for countries worldwide. The increasing waste streams are entering the ecosystem and further deteriorating the health of citizens worldwide. An emerging economy like India, which offers a key market for electronic devices, shares a greater concern for appropriate e-waste management practices. The present study focuses on the growth of academic literature in this field and its future direction. It utilizes the PRISMA method of systematically analyzing the literature in the field. It reports increased publications and the major countries generating this academic data. It also highlights the prominent studies in the field and the conclusions derived. A systematic literature review utilized VOS viewer software and Atlas Ti for generating bibliometric images. The review finally suggests the broader theme areas covered in this domain and the research direction researchers in the field may explore.



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Introduction


With the world moving towards sustainable behaviors, electronic waste offers new challenges to countries worldwide. According to the definition given under the Basel Convention, the Waste Electrical and Electronic Equipment (WEEE) is defined as "electrical or electronic equipment that is waste, including all components, sub-assemblies and consumables that are part of the equipment at the time the equipment becomes waste." As per the Global E-waste Monitor 2019,¹ only 17.4%

of the total e-waste generated (53.6 million metric tons) was efficiently managed worldwide. It increased to 1.8 Mt in 2014, but the total e-waste generation significantly increased to 9.2 Mt in 2019. Thus, there is a considerable gap between the e-waste generated and recycled globally. The continent which reported the most efficient management of e-waste was Europe (42.5%), further led by Asia (11.7%) and henceforth by America (9.4%) and Oceania (8.8%) and then by Africa (0.9%) having the lowest rate.¹

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India discards around 1.7 million tons (Mt) of e-waste, making it the fifth largest producer of electrical and electronic waste in the world as per UN report.² Hence, it becomes imperative to understand the current scenario of e-waste management in an emerging economy like India. Thus, both the countries and consumers need to focus on consumption patterns and behaviors towards the purchase and disposal of these items^{3,4}

Studies carried out in the field of e-waste management have particularly focussed on the challenges and issues ahead of countries worldwide (5,6). A life cycle analysis of e-waste, the production process itself involves a great deal of hazardous byproduct generation.⁷⁻⁹ After production, the purchase process by the consumers and their use also involves a lot of behavioural implications. Studies suggest using e-waste software and e-waste lenses, suggesting various strategies for effective electronic material handling and supply chain software management, which can lead to effective and efficient resource usage.^{4,10} The usage of blockchain technology, which is centred around tracking the origin, location and history of a device, has also been stated as a novel method to bring about real-time tracking and monitoring of the e-waste management chain.¹¹⁻¹⁴

Garg *et al.*¹⁵ have reported that with the rapid technological changes and upgradation in gadgets, consumers upgrade their electronic devices at an alarming rate. The increased availability and multiple brands in electronic gadgets have also led to increasingly smaller life cycles of product use with the consumer, leading to increased e-waste generation.¹⁶⁻¹⁸ However, studies by Laeequddin *et al.*¹⁹ related to consumer intention towards safe disposal of their e-waste have reported that no direct regulations aid to influence consumer safe disposal intentions. Perceived social norms extend producer responsibility, and clear communication may aid in bringing out significant changes in consumer intentions.²⁰⁻²²

Most of the challenges are related to the health implications for citizens arising from uncontrolled waste.²³⁻²⁵ Further research in this area requires to be focussed on an amalgamation of e-waste and circular economy. This will ensure the waste resources are extracted, reused, and valued. This

will aid in creating decent, sustainable jobs also eventually.^{26,27}

Hence, the present study envisages the contribution made by various authors to developing this field of study, focusing on its further development. The novelty of this study lies in addressing the studies which present the emerging trends in this topic in the emerging economy of India. The growth in the consumer electronics market systematically necessitates proper e-waste management through policy and practice.²⁸ Besides, most of the electronic waste in India is still in the hands of the unorganized sector. It also attempts to explore answers to the following questions,

The present placement of “e-waste” in the literature? What are the prominent areas being emphasised by researchers?

Which countries are contributing more literature to the field?

What is the relative position of India in the e-waste management field?

Which keywords are prominently used by authors in the e-waste domain in India?

Materials and Methods

The study incorporates the bibliometric analysis to analyse the recent practices in the field. The search was restricted to the Scopus database, which utilized the data from 2006 to 2023. Scopus database has been considered as it is known for its quality standards and wide coverage of information related to specific knowledge bases.^{29,30} The search with keywords “E-waste” and “India” resulted in 1595 articles. The studies on e-waste carried out in the context of the Indian territory were focussed upon for the study. The criteria for selection in the study were based on the PRISMA statement.³¹ The PRISMA items are the reporting methods used in the systematic literature review. The steps have been illustrated in Figure 1. Articles from all over the world have been included without the exclusion of any country. Abstracts of all these articles were included in the study and were reviewed thoroughly to exclude any duplications. In the data extraction phase, 211 documents were selected, and the following characteristics were retained as the inclusion criteria: Articles must be original papers, review papers or an editorial. Conference papers and case studies were also included.

The language used in the article must be English, and it should relate to any of the fields, including etc.

Extracted articles must be published during the period 2006-2023.

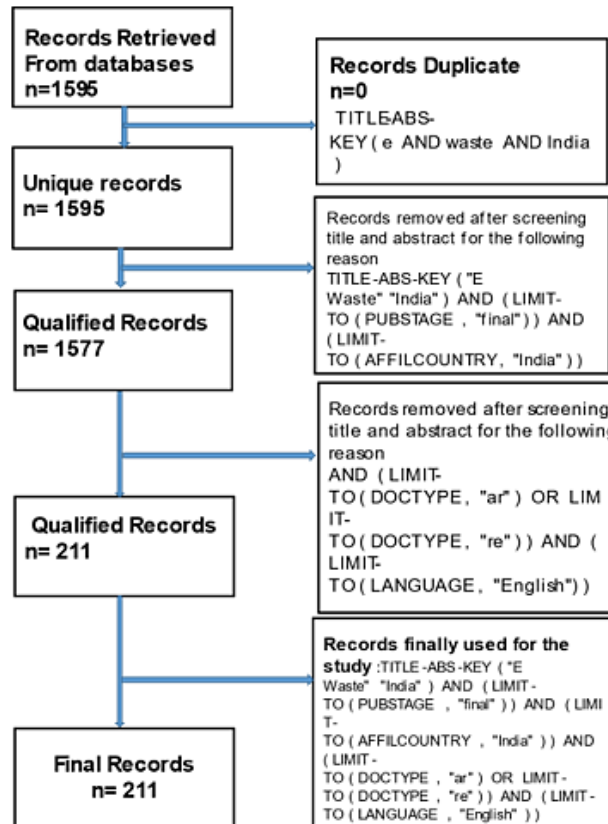


Fig. 1: PRISMA methodology

For the Bibliometric analysis VOS viewer program and Atlas Ti has been utilised to generate the visual maps based on the data extracted from various database. The research uses the network visualization technique whereby the labels represent the items they carry, and a circle represents the weight. Both the label and circle represent the total weight of the item. The greater the weight of the item, the bigger the circle. The colour reflects the cluster to which the item belongs. The distance between the circles indicates the relatedness of the items. Atlas Ti has been used to generate the concept mapping of the keywords used in the various studies. This study utilizes the Scopus database for extracting the studies based on e-waste studies in India. Various parameters like authors, co-authorship and citations have been used to generate visual maps. As per some studies³² the quality and impact of research can be effectively analysed through the number of

research citations. After the quantitative analysis, the study followed the qualitative analysis of the articles and selected 211 relevant papers related to the field. The research uses the network visualization technique whereby the items reflect the label they carry and by a circle. Both the label and circle reflect the total weight of the item—the more the weight, the bigger the circle. The colour reflects the cluster to which the item belongs. The distance between the circles indicates the relatedness of the items.

Results

A comprehensive review of the studies carried out in the domain of e-waste in the Indian context has been listed in Table 1. Most of these studies are review articles and policy-related studies focussing on the contemporary and future challenges of e-waste management.

Table 1: List of Studies on E-waste in Indian context

Name of the Article	Author/s	Type of Study	Results	Limitations
Managing E-Waste in India- A review	³³ Saini A, Taneja A	Review Article	Conversion of waste to wealth through effective management of waste	Limited to specific waste types in the Indian context
India's E-waste Rules and Management	³⁴ Bhaskar K, Turaga R	Case Study/ Interview based	Extended producer responsibility policy considers instruments such as a deposit-refund system.	Only limited stakeholders located in Ahmedabad city were involved in the study.
An overview of E-waste practices	³⁵ Rajput R, Rinki, Nigam N	Review Article	Urbanization contributes to increased e-waste streams in the Indian context.	Limited to policies and legislation in the Indian context
E-waste: A new challenge for waste management	³⁶ Mundada M, Kumar S, Shekdar A	Empirical research	Present the waste stream generated and the course of action to be taken.	Focussed only on computer waste management
Sustainability through remanufacturing of e-waste:	³⁷ Singhal D, Tripathy S, Jena S	Exploratory	The study reflects the absence of autonomous factors by consumers of electronic goods.	Focussed only on the strategy of remanufacturing
E-Waste: Issues and Strategies	³⁸ Turaga R, Bhaskar K, [...] Sharma H	Descriptive	Recent management of e-waste and the challenges ahead	Focussing only on extended producer responsibility
Review of the Policy regarding e-waste in India	³⁹ Borthakur A	Review Article	Current e-waste policies in India and the need for localized policies	Focussed only on legislative goals
Management of e-waste in India	⁴⁰ Jain S, Garg K	Exploratory	Focussed on Global agreements on e-waste disposal	Focuses on certain methods of waste disposal and their advantages
E-waste management in India	⁴¹ Balakrishnan C, Rachel Priya J	Review	Generating awareness of the repercussions of improper e-waste disposal	Focussed only on the consumer perspective of waste generation and disposal

A year-wise analysis of the 211 documents, as reflected in Figure 2, results in the maximum number of articles contributed by authors in the year 2021 and the initiation of the studies incorporating

behavioral aspects from the year 2004. This year already, fifteen articles have been contributed to this field of study.

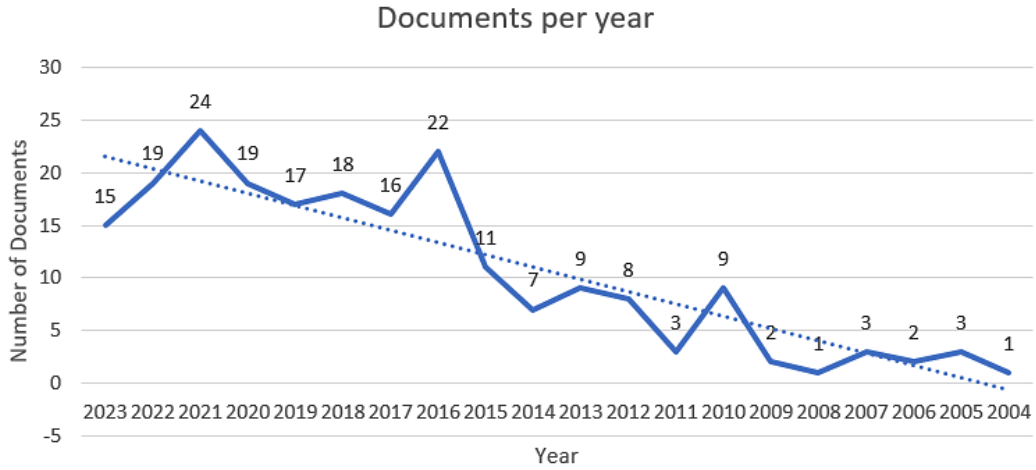


Fig. 2: Year-wise analysis of the Scopus database

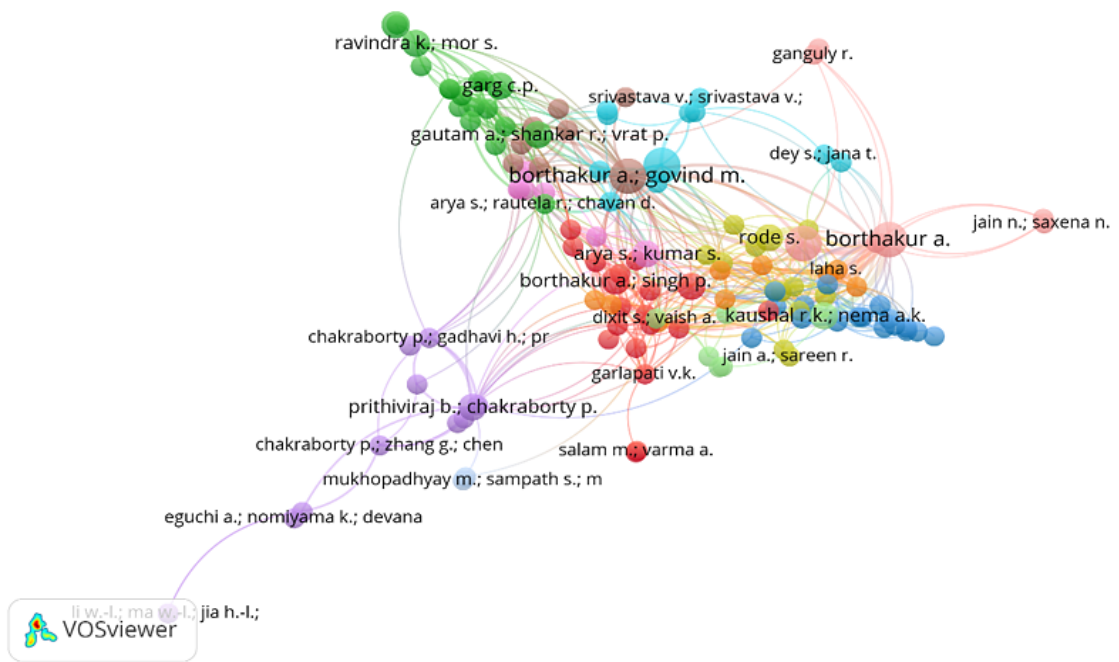


Fig. 3: Author wise analysis

The data suggests that there has been a constant rise in the number of studies related to e-waste. The Author-wise analysis (Figure 4) based on the citations increased the visibility of authors like Borthakur, A., Dwivedi, M., Chaudhary, K., Govind, M., Mittal, R.K.

The country-wise analysis (Figure 5) suggests a prominence of research from India in this field. This is further followed by research from the USA, China, South Korea, and Japan.

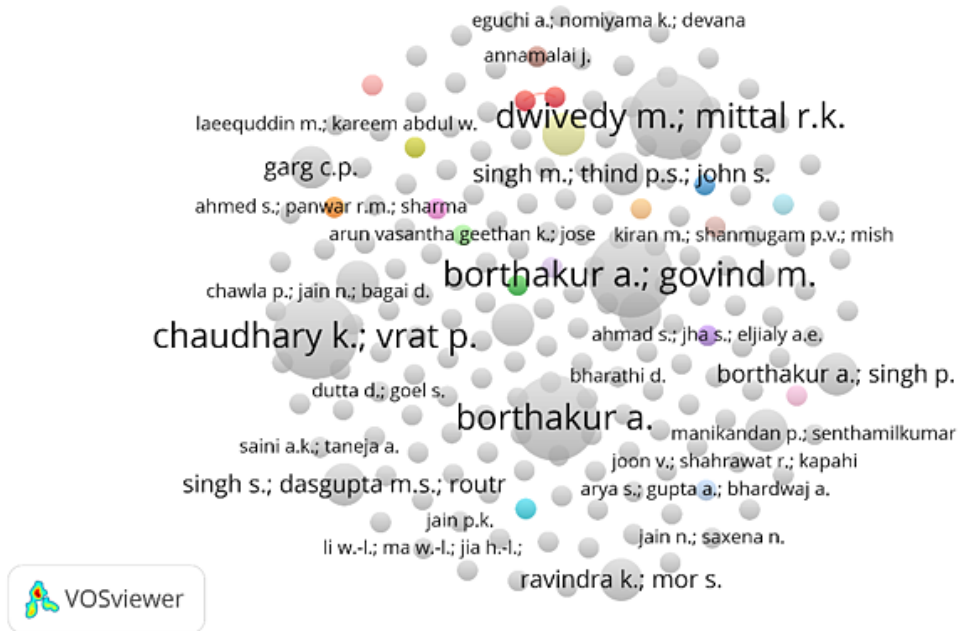


Fig. 4: Author-wise based on citations

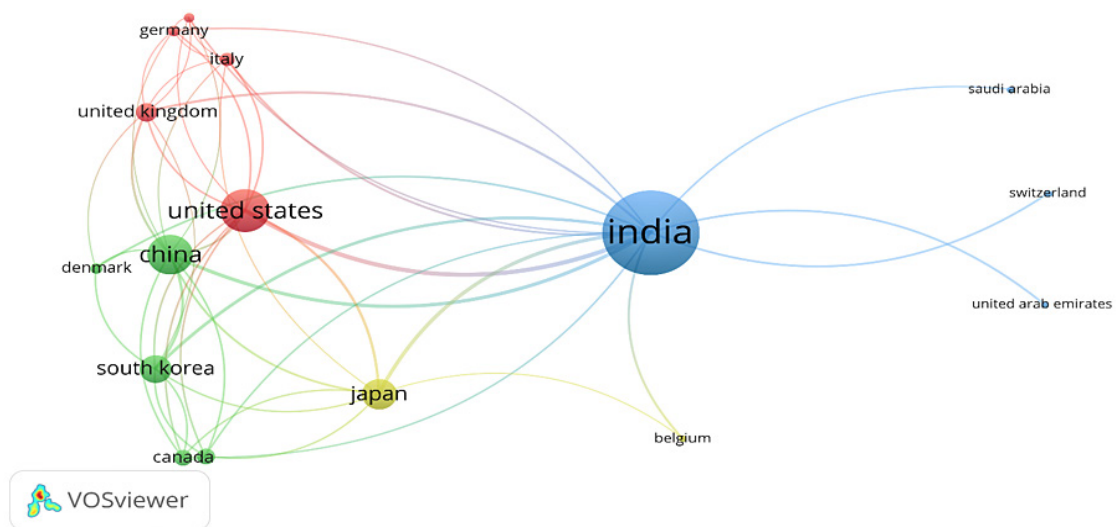


Fig. 5: Country Wise Analysis

The binary counting method (Figure 6) results in terms like soil, site circuit board, PCBs, Usage, etc. The colours reflect the clusters to which the keyword belongs. The maps for keyword content analysis have been performed through binary and full counting methods. In the case of binary counting, the occurrences reflect the number of occurrences of terms at least once in the documents.

On the other hand, in full counting (Figure 7), the occurrences reflect the total number of occurrences of a term in all documents. Both methods have been used for keyword analysis. The full counting method enhances the visibility of waste management systems, sites, PCB, Intention and Municipal corporations.

Discussion

There has been an increase in the studies related to contemporary management practices related to e-waste. The figures indicate an increase in the number of documents from 1 in 2004 to 15 in 2023. Thus, there has been increased attention being provided in the academic arena in this field.

The clustering reflects the prominent areas such as waste recovery, the role of the local bodies and the resident attitude towards e-waste management. Most of the research has been carried out stating the ill impact of this waste on the surrounding environment.⁴²⁻⁴⁴ Thus arises a significant challenge of handling this waste scientifically wherein important resources are recovered from the waste, and then the remains are safely disposed of. Several studies^{45,46} have also assessed the risk associated with the workers engaged in the recycling industry associated with e-waste. There also appears to be a greater risk with the open dump sites where no protective shields are provided to the workers. It thus emerges as an emerging public health challenge for the various stakeholders^{23,47} Thus. There is an urgent need to manage this waste effectively and efficiently and sustain the various components of the ecosystem being damaged by this waste penetration⁴⁸⁻⁵⁰

The data concerning the country statistics reflects that the greatest number of published articles are in India compared to the US and China. The study results contrast with those reported by researchers^{51,52} followed by Japan, Canada, UK, and Germany. Since the severity of the problem rests highest in India, the concern is also high in developing nations like India for bringing out effective e-waste management. Most relevant articles with the term E-waste in the Scopus database have been contributed by authors from various fields.

Another limiting gap is the lack of studies in India related to the informal setup of the collection measures.⁵³⁻⁵⁶ Studies have emphasised the role of the parallel economy being run through the informal recycling facilities in India. There should thus be a policy and provision for governing the informal network and formalizing this sector slowly.^{57,58} The

keywords prominently used in the studies are waste, management, city, system and collection.

Another relevant information from this study is that the studies in this field have yet to focus on a complete life cycle analysis of e-waste. This calls for an urgent need to carry out studies which can analyze the cradle-to-grave features of this type of waste. This might help bring in early interventions and design policies and practices which cater to the stage-based need for e-waste management. Also, it might result in increased efficiency of waste identification and collection. The keywords suggest the underpinning of the research in related areas of e-waste management and its adverse influence on health and the sites where the waste is being dumped. Hence, studies should prioritize the intentions and attitudes of the residents while also simultaneously stressing the urgent need for proper e-waste management.

Conclusion

E-waste has been increasing at an alarming rate worldwide. It has captured the attention of policymakers and various stakeholders as it might create a burgeoning issue in the future. India, being a leader in consumer markets waste generation in future, is also likely to be on the higher end. The field of e-waste management has gained increased impetus from the academic community as many studies are being conducted to explore and envisage the best management practices for this waste. The results suggest that several publications are from developing countries like India, focusing on process management and resident attitudes toward managing e-waste. This study contributes to the identification and classification of numerous studies in e-waste management in India and reports the emergent trends in e-waste. Future studies should focus more on waste characterisation and specific methods to handle these waste streams. Studies should also focus more on consumer intention towards sustainably handling this waste.

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Conflict of Interest

The authors declare no conflict of interest.

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