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RESEARCH PAPER

Towards a Greener Tomorrow: Investigating Future Directions of e-Waste Management through Bibliometric Analysis

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ABSTRACT

Electronic waste, commonly known as e-waste, has emerged as a significant global waste stream, prompting extensive scholarly investigation into its trends. This study aims to conduct a bibliometric analysis to examine journals, authors, countries, and keywords, as well as to probe prevailing themes and future trajectories in e-waste research. The authors utilized the Scopus database for data retrieval and employed VOSviewer software for analysis. The findings reveal a notable surge in publications pertaining to e-waste studies within the domain of business, management, and accounting, particularly in the top 10 ABDC journals of A*/A quality. China emerges as the leading country in this research area, with the Journal of Cleaner Production being the most prolific publisher. The International Journal of Production Economics garners the highest citation score, and Elsevier stands out as the top publishing house. Notably, Li Jinhui and Xu Zhengming from China have authored most articles. The primary focus of e-waste studies centers around recycling. Additionally, the authors conduct cluster analysis to propose potential themes for future research directions. Future researches can be conducted on impact of e-waste on climate change and awareness among people about e-waste.

| **KEYWORDS** | Bibliometric Analysis, Business, E-waste, Management and Accounting, Scopus Database, VOS viewer |

Introduction

The electronics industry, driven by the emergence of advanced technology and innovative devices, plays a pivotal role in driving global economic growth (Dias et al., 2019; Gao et al., 2019). However, the frequent replacement of old devices with new ones and the rapid usage of electronic equipment in our daily lives, without proper recycling, has raised concerns as products reach their end-of-life stage, commonly referred to as E-waste or electronic waste (Garlapati, 2016; Tansel, 2017). E-waste has swiftly evolved into one of the largest waste streams worldwide (Guo et al., 2015). While developed countries employ formal methods of e-waste recycling through collection centers and treatment facilities, developing nations like Pakistan, China, and India largely rely on informal recycling methods (Borthakur & Govind, 2018; Shaikh et al., 2020; Rasheed et al., 2022).

E-waste exerts a significant environmental impact due to its inclusion of toxic and hazardous materials such as arsenic, lead, mercury, and cadmium. These substances can pose risks to both the environment and human health, as they can be inhaled through air, ingested via food, or absorbed through water, leading to potential health issues including cancer, allergies, and other major diseases (Rasheed et al., 2022; Nixon et al., 2009).

Despite the importance of this subject, there have been limited bibliometric analyses on e-waste, and those that do exist have been based on research data up until 2018 (Chen

et al., 2021; Zhang et al., 2019; Gao et al., 2019). Moreover, within the Scopus database, there is a scarcity of bibliometric studies in the field of business, management, and accounting (Iandolo et al., 2021), an area often overlooked in this context (Cortés-Sánchez, 2020). Therefore, this research study aims to investigate the global research trends on e-waste in the business, management, and accounting domain, utilizing bibliometric techniques from the top 10 ABDC journals of A*/A quality. The study spans from 1995 to March 2023, providing a comprehensive overview of current progress and suggesting future directions for e-waste research. The objectives of this study are twofold: i) to analyze journals, authors, countries, and keywords pertaining to e-waste, and ii) to explore existing themes and future directions in e-waste research.

Bibliometric analysis, a quantitative tool employed to extract measurable and valuable data from literature (Shi et al., 2020; Chen et al., 2021), allows for the quantification of trends in journals, authors, countries, institutions, and keywords relevant to the study (Chen et al., 2016; Gao et al., 2019).

Literature Review

Banu et al. (2022), assessed the awareness of E-waste disposal behaviour and readiness to pay for recycling in Oman. They found that 31% of families are willing to pay for recycling the E-waste and that 84.5% of households are uninformed closest location of E-waste facility. Fan et al. (2022) looked at how different motivating rules and the moderating effect of customer gender affected e-waste disposal behavior. They noticed that female customers are more motivated to dispose of their electronic waste than male customers are. Rasheed et al. (2022) examined the financial advantages of managing e-waste in underdeveloped nations like Pakistan, they found that effective recycling can lessen the impact on natural resources by 80%. According to Najmi et al. (2021), it is the obligation of the producer to manage the e-waste and consumer participation must be promoted regarding this issue.

Material and Methods

Data Source and Search Strategy

Retrieval of data was done in a single day to avoid any updates in the Scopus database. The process of data gathering is summarized in Figure 1.
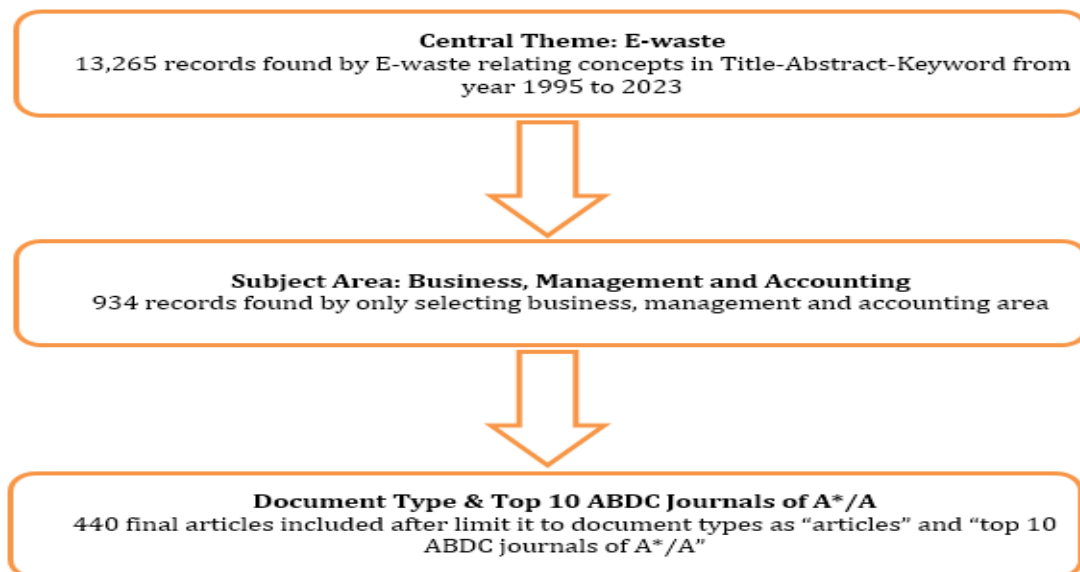

Figure 1 Flowchart of Data Gathering

Statistical Analysis

According to Zhang et al. (2018), VOSviewer software is being widely used in bibliometric analysis to find out top countries, institutions, and frequently used keywords. Authors used VOSviewer (version 1.6.19) software to analyze year, authors, countries, institutions, journal, and keywords. After that, authors generated network maps for countries and keywords, then performed cluster analysis. There are several links and nodes in the network map and each node represents one country and keywords.

Results and Discussion

Publication Trend

Figure 2 represents the publication trend in term of year and articles/documents, where publication years are on X-axis and number of documents are on Y-axis. According to Figure 2, the first publication was done on e-waste in business, management, and accounting area in top 10 ABDC journals of A*/A in 1995 and till 2003 number of publications were quite low. After 2004, it gains popularity, and more research came out in this field. From last 7 to 8 years number of publications increased rapidly such as 50 articles in 2016, 57 articles in 2017, 75 articles in 2018, 71 articles in 2019, 87 articles in 2020, 89 articles in 2021 and 74 articles in 2022 have been published relating to e-waste in business, management, and accounting area. This area is still interesting, and many researchers are working on it. Researchers can check its significance from this data that just three months have been gone in 2023 and 24 articles have been published.
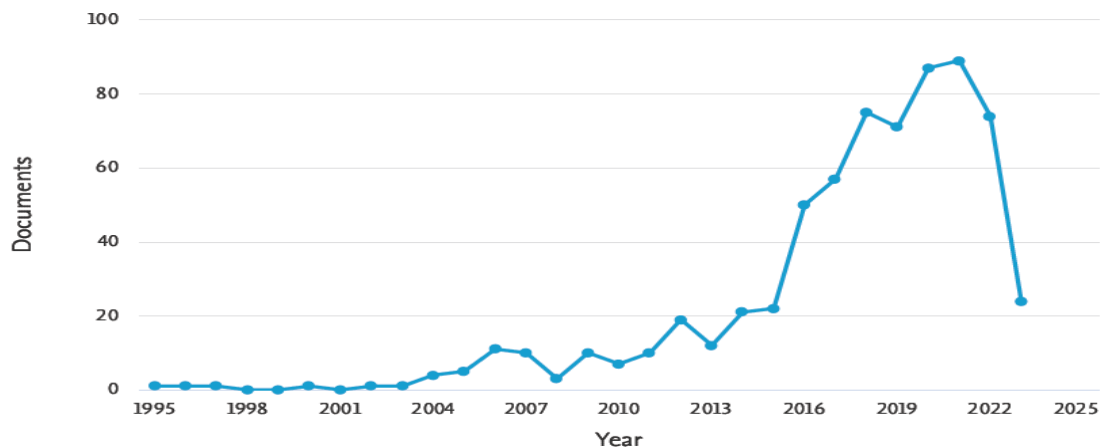

Figure 2 Publication Trend

Analysis of Journals

Authors have limited this search to the top 10 ABDC journals of A*/A relating to e-waste in business, management, and accounting area. 440 articles have been published by top 10 ABDC journals of A*/A in business, management, and accounting area from 1995 to March 2023. Table 1 presented the top 10 journals, with their ABDC category, number of publications by each journal relating to e-waste in business, management, and accounting area, their cite score and publisher's name of the journal. Journal of Cleaner Production (374 articles, 85%) published most of the articles related to e-waste in business, management and accounting area followed by International Journal of Production Economics (16 articles, 3.6%), International Journal of Production Research (14 articles, 3.2%), Business Strategy and the Environment (8 articles, 1.8%), Technological Forecasting and Social Change (8 articles, 1.8%) and so on. International Journal of Production Economics has the highest cite score among all journals that is 19.1 and Journal of the Operational Research Society has the lowest cite score among all journals that is 5.4. In terms of publisher, Elsevier is the top

publisher with 3 journals, followed by Wiley-Blackwell and Taylor & Francis have 2 journals each. 2 out of 10 journals (Production and Operations Management, Management Science) have A* in ABDC journal category and rest of them have A in ABDC journal category.

Table 1
Summary of Top 10 Journals with total Publication and Cite Score

Rank	Journal Name	ABDC Category	Number of Publications (%)	Cite Score 2022	Publisher
1	Journal of Cleaner Production	A	374 (85%)	18.2	Elsevier
2	International Journal of Production Economics	A	16 (3.6%)	19.1	Elsevier
3	International Journal of Production Research	A	14 (3.2%)	17.8	Taylor & Francis
4	Business Strategy and the Environment	A	8 (1.8%)	17.7	Wiley-Blackwell
5	Technological Forecasting and Social Change	A	8 (1.8%)	16.9	Elsevier
6	Production and Operations Management	A*	7 (1.6%)	6.5	Wiley-Blackwell
7	IEEE Transactions on Engineering Management	A	4 (0.9%)	7.4	IEEE
8	International Journal of Logistics Management	A	3 (0.7%)	8.3	Emerald
9	Journal of the Operational Research Society	A	3 (0.7%)	5.4	Taylor & Francis
10	Management Science	A*	3 (0.7%)	7.8	INFORMS

Authorship Analysis

Figure 3 presented the top authors who published articles in top 10 ABDC journals of A*/A relating to e-waste in business, management, and accounting area. Li, Jinhui and Xu, Zhengming from China are the top productive authors who published 11 articles each relating to e-waste in business, management, and accounting area. After them Sahajwalla, V. and Song, Q. published 8 articles each, He, Y., Huda, N., and Zhang, G. published 7 articles each, Sun, Z., Wu, Y., and Zhang, T. published 6 articles each relating to e-waste in business, management, and accounting area.
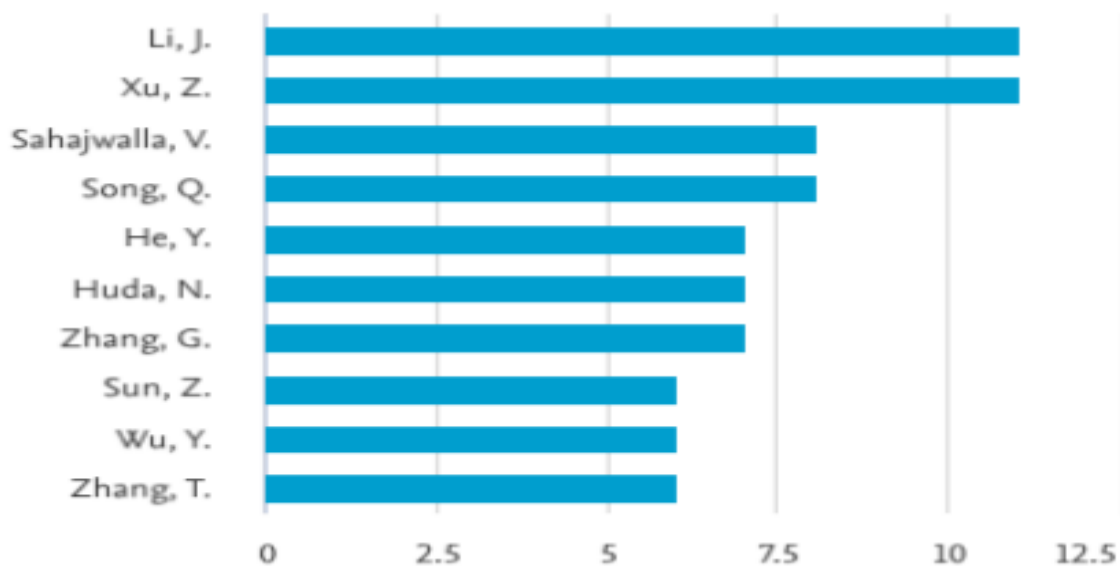

Figure 3 Documents by Author

Table 2 also highlighted more details about top 10 authors in terms of when their 1st article published, their total publication, total citation of their published work, h-index, author's current affiliation and from which country they belong. In term of top 10 authorship analysis, Sahajwalla from Australia has published 458 articles and his article was 1st published (1994) among all top 10 authors. Li Jinhui from China has more total citation (13,860 times) and highest h-index (67) among all top 10 authors. It has been also observed that 8 out of top 10 authors are from China and remaining 2 from Australia, which shows that Chinese researchers are paying more attention on e-waste related research.

Table 2
Top 10 Authors and Affiliations

Rank	Author	Year of 1st Publication	Total Publication	h-index	Total Citation	Current Affiliation	Country
1	Li, Jinhui	1998	371	67	13860	Tsinghua University, Beijing	China
2	Xu, Zhengming	1995	314	50	9632	Shanghai Jiao Tong University, Shanghai	China
3	Sahajwalla, Veena	1994	458	49	9931	UNSW, Sydney	Australia
4	Song, Qingbin	2012	89	32	3234	Guangdong-Hong Kong-Macao Joint Laboratory for Contaminants Exposure and Health, Guangzhou	China
5	He, Yaqun	2001	187	30	3169	China University of Mining and Technology, Xuzhou,	China
6	Huda, Nazmul	2009	74	27	2499	Macquarie University, Sydney	Australia
7	Zhang, Guangwen	2016	38	23	1301	Info China University of Mining and Technology, Xuzhou	China
8	Sun, Zhi	2007	148	37	5448	Chinese Academy of Sciences, Beijing	China
9	Wu, Yufeng	2006	153	33	3238	Info Beijing University of Technology, Beijing	China
10	Zhang, Tao	2010	66	24	1668	State Key Laboratory for Geo Mechanics and Deep Underground Engineering, Xuzhou	China

Countries and Continents Analysis

55 countries participated in the research publication of e-waste in business, management, and accounting area. According to Table 3, China is top most country who published 36.1% articles followed by USA (10.7%), Australia (9.1%), India (8.6%), Italy (6.1%), UK (5.9%), Canada (5%), Germany (4.3%), Brazil (4.1%) and Taiwan (4.1%). In term of continents, 23 Asian countries participated in e-waste publication followed by 20 European countries, 7 American countries, 4 African countries and 1 Australian country. China is among top Asian country, Italy is among top European country, USA is among top American country and Egypt is among top African country who participated in e-waste related publication in top 10 ABDC journals of A*/A in business, management, and accounting area.

Table 3
Top 10 most productive countries

Rank	Country	Publication (%)	Continent
1	China	36.1	Asia (23 Countries)
2	United States	10.7	Europe (20 Countries)
3	Australia	9.1	America (7 Countries)

4	India	8.6	Africa (4 Countries)
5	Italy	6.1	Australia (1 Country)
6	United Kingdom	5.9	
7	Canada	5	
8	Germany	4.3	
9	Brazil	4.1	
10	Taiwan	4.1	

Figure 4 showed the collaboration of the countries that published articles related to e-waste. The larger the size of a country indicating larger the number of publications of that country and same color indicates clusters of strongly related countries (Liang et al., 2018). Here, China takes the top position who make collaboration with other countries and its total link strength (measure the overall strength of collaboration between countries through their co-authorship) is 70 followed by USA with 39, Australia with 26, India with 24 and Italy with 21 total link strength.
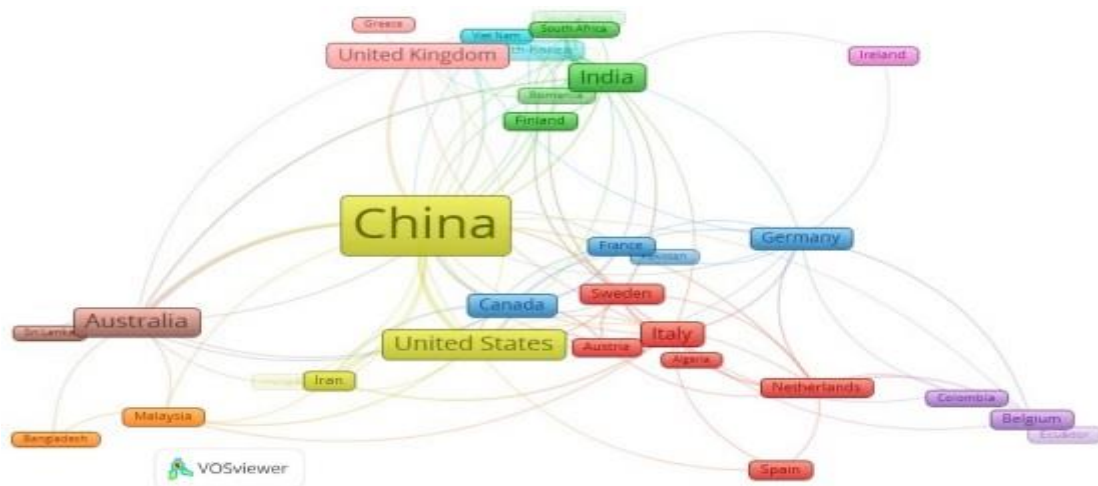

Figure 4 Network Map of Countries for E-waste Research

Keyword Analysis

Keywords are the core content of an article that helps researchers to find out the research trends and identify main concepts in the article (Zhang et al., 2019). In total, 42 keywords were obtained who have minimum occurrence 5 times from 440 publications. According to Table 4, "e-waste" and "recycling" both are the top most frequently used keyword with a frequency of 73 and 72 respectively. After them "WEEE" occurred 43 times, "Circular Economy" 39 times, "Electronic Waste" 27 times, "Life Cycle Assessment" 21 times, "Sustainability" 18 times, "Reverse Logistics" 16 times, "Extended Producer Responsibility" 14 times and "Recovery" occurred 13 times. "E-Waste", "WEEE", "Electronic Waste", "Waste Electrical and Electronic Equipment" and "Waste Electrical and Electronic Equipment (WEEE)" are the different names of same concept (E-waste), so it can be considered as one keyword.

Table 4
Top 10 Keywords with Frequency

Rank	Keyword	Frequency of Occurrence
1	E-Waste	73
2	Recycling	72
3	Weee	43
4	Circular Economy	39

5	Electronic Waste	27
6	Life Cycle Assessment	21
7	Sustainability	18
8	Reverse Logistics	16
9	Extended Producer Responsibility	14
10	Recovery	13

According to Zhang et al. (2019), keyword co-occurrence analysis identifies the relationship between two keywords based on their frequency of occurrence in the same literature. Finding of keywords co-occurrence analysis in Figure 5 reflected that the research related to e-waste mainly focuses on recycling, sustainability, resource recovery and its impact on circular economy.

Authors also performed cluster analysis (Figure 5) on co-occurrence analysis, so authors clustered the 42 keywords into three categories. Cluster 1 mainly focused on E-waste, WEEE, circular economy, sustainability, environmental impact and remanufacturing; cluster 2 mainly focused on recycling, electronic waste, resource/metal recovery and talking about different polluted chemicals; and cluster 3 mainly focused on E-waste management, China and waste electrical and electronic equipment.
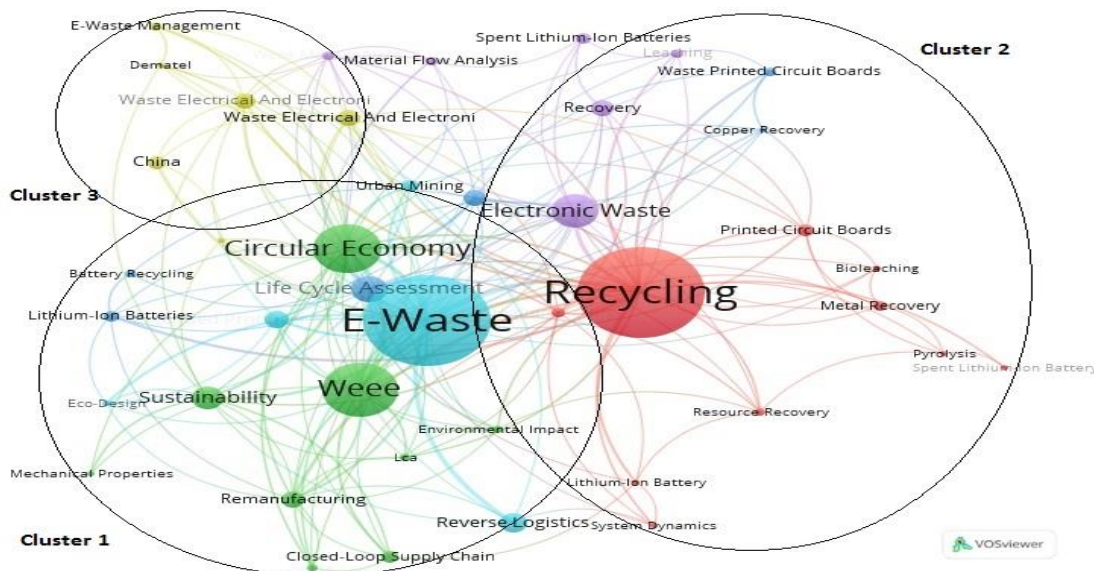

Figure 5 Network Map of Keywords for E-waste Research

Moreover, the authors developed 3 clusters (see Figure 5) from the extracted data details of which are given below.

Cluster 1

Authors named cluster 1 as E-waste and recycling because in this cluster, research articles are relating to recycling, resource, and metal recovery from E-waste.

Cluster 2

Authors named cluster 2 as E-waste and sustainability because in this cluster, research articles are relating to sustainability, environmental impact circular economy and remanufacturing from E-waste.

Cluster 3

Authors named cluster 3 as E-waste management because in this cluster, research articles are relating how to manage e-waste and authors found this cluster as smallest one among all so more work can be done regarding e-waste management.

Discussion

The comprehensive findings of this study highlight the escalating presence of e-waste, driven by the proliferation of new electronic devices. Consequently, scholarly interest in this domain has surged significantly. In order to discern key research trends and gather pertinent data on e-waste, the authors employed a bibliometric analysis. Their investigation revealed a substantial corpus of 13,265 articles published between 1995 and 2023, sourced from the Scopus database. This extensive body of work underscores the widespread examination of e-waste from various disciplinary angles and perspectives.

When the analysis was refined to consider specific document types (articles), subject areas (business, management, and accounting), and publications from the top 10 ABDC journals of A*/A quality, the dataset was narrowed down to 440 articles. Notably, the Journal of Cleaner Production emerged as a pivotal source of research on this topic. China assumed a paramount role as the most influential contributor, accounting for the majority of publications. Additionally, eight out of the top ten authors hailed from China, with Li Jinhui and Xu Zhengming leading the ranks in terms of authorship contributions.

Conclusion

Last but not least this research study gives a comprehensive overview of publications relating to e-waste and aid in identifying potential future research areas for anyone working in this field. Research on e-waste has focused heavily on its effects on the environment and human health, however, has received insufficient attention. More consideration should be given to the characteristics of e-waste. The future direction and strategy for managing and recycling e-waste will be beneficial for the whole society.

Future Directions

A comprehensive overview of e-waste can help researchers to explore it more or find new directions such as impact of e-waste on climate change, resources (land, water and air) pollution, poverty and education or awareness about e-waste. Future research can also be conducted to find the answer of "why China and other Asian countries are the center of main research on e-waste?"

Implications and Limitations

The outcomes of this study bear significant relevance for individuals aiming to enhance their immediate environment. Industrial workers, too, stand to benefit by implementing advanced technologies and diverse e-waste recycling methodologies. Furthermore, researchers can leverage bibliometric analysis to gain deeper insights into the subject matter.

It's worth noting that during data screening, there's a possibility that certain noteworthy publications may have been overlooked. This limitation arises from the authors' utilization of a single database for bibliometric analysis, along with the application of specific filters pertaining to document type, subject area, and top-tier journals. As a result, future research endeavors could explore additional databases without imposing similar filters to ensure comprehensive coverage. Despite our efforts to refine the keywords for data analysis, there remains a margin for potential omissions.

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