Environment and Natural Resources Journal

Volume 23
Issue 3
2025

Research Trends in Organic and Inorganic Waste Sorting Technology: A Bibliometric Analysis

Mahliza Nasution[1*], Muhammad Irwansyah[2], Hermansyah[1], and Rospita Gultom[1]

[1]*Faculty of Engineering, Universitas Medan Area, Indonesia*
[2]*Faculty of Engineering, Universitas Asahan, Indonesia*

ARTICLE INFO

Received: 4 Nov 2024
Revised: 27 Jan 2025
Accepted: 10 Feb 2025
Published online: 25 Mar 2025
DOI: 10.32526/ennrj/23/20240277

Keywords:
Research trends/ Organic and inorganic waste/ Waste sorting/ Artificial intelligence

*** Corresponding author:**
E-mail: mahliza@staff.uma.ac.id

ABSTRACT

This research presents major trends in organic and inorganic waste sorting technology over the past 20 years (2003-2023). To do so, we employed bibliometric analysis and VOSviewer and Biblioshiny software. The data used in this study included 810 documents from the Scopus database. This study also used literature analysis of 11 documents discussing the use of AI in organic and inorganic waste sorting technology. The results showed that leading journals covering the topics 'Waste Management and Resources', 'Conservation', and 'Recycling', had the highest publication volume and total citations. Journals in China also had high volume and citations. The literature analysis of the articles further showed that integrating AI into waste-sorting technology can improve organic and inorganic waste-sorting efficiency and effectiveness, and also contribute to sustainable environmental planning. Future research opportunities include enhancing AI accuracy in waste sorting, developing renewable waste-to-energy technologies, and promoting interdisciplinary collaboration to advance sustainable waste management solutions.

HIGHLIGHTS

1. This study reviews research trends in waste sorting tech from 2003 to 2023.
2. Bibliometric analyses used VOSviewer and Biblioshiny on 810 Scopus documents.
3. AI integration enhances sorting accuracy, driving sustainable waste management solutions.

1. INTRODUCTION

Rapid population growth indirectly leads to an increase in waste production; unfortunately, an ineffective waste management system will accumulate waste at the final processing site. This accumulation of waste can potentially produce gases that are harmful to health and the environment (Harjanti and Anggraini, 2020). Indonesia is one of the countries dealing with increasing plastic waste, which has become a serious concern. According to Indonesian data from the Ministry of Environment and Forestry's National Waste Management Information System (SIPSN) for 2022, with input from 2022 districts/cities throughout Indonesia, national waste generation reached 21.1 million tons. Of the total national waste production, 65.71% (13.9 million tons) can be managed, while the remaining 34.29% (7.2 million tons) needs to be managed properly (Rahmatullah, 2023). Based on its nature, waste can be classified into organic and non-organic (Djawad et al., 2022). Organic waste is easily recyclable waste, does not harm the environment, and can be decomposed with the help of microbes. Nevertheless, organic waste still requires careful handling, if not properly processed, it can become a source of odor that disturbs environmental comfort and contributes to environmental pollution (Febriadi, 2019). On the other hand, inorganic waste is made of inorganic materials whose decomposition process takes a very long time (Dzakiya et al., 2019).

In general, waste sorting is still done manually using human hands. Nurdin et al. (2020) stated that

Citation: Nasution M, Irwansyah M, Hermansyah, Gultom R. Research trends in organic and inorganic waste sorting technology: A bibliometric analysis. Environ. Nat. Resour. J. 2025;23(3):232-241. (https://doi.org/10.32526/ennrj/23/20240277)

waste management can be implemented with the 3R principle: reduce, reuse, and recycle. Reduce is an effort to reduce waste generation in the environment at its source even before waste is generated (Arisona, 2018). Each source can contribute to reducing waste by changing its consumption habits, especially switching from wasteful habits that produce much waste to economical, efficient ones that produce little waste. Meanwhile, reuse refers to the reuse of materials or resources so that they do not end up in the trash. Examples include filling milk cans with refillable milk, using paper back and forth, and reusing used beverage bottles into drinking water containers (Junaidi and Utama, 2023). Recycling is one way to reduce existing waste, namely by making waste something that can be reused (Siagian et al., 2022).

Since the waste-sorting process is still done manually, it requires much time and energy. Therefore, the right solution is needed to speed up and simplify sorting organic and non-organic waste (Wibysono et al., 2022). The volume of waste can be gradually reduced by classifying waste correctly so that waste processing becomes easier (Aulia et al., 2021). The use of AI technology helps sort and recycle waste. Artificial intelligence (AI) in waste management is becoming increasingly important in countries worldwide, including China and Europe. AI technology optimizes waste collection routes in major cities such as Shanghai and Beijing. For example, intelligent waste collection systems use sensors and AI algorithms to monitor the volume of waste in each area and plan the most efficient collection routes (Zhu et al., 2019). AI has also become common in waste management in some European countries, such as Sweden and Norway. AI technology monitors and optimizes waste collection, identifying the most efficient collection routes based on volume and time data (Rekabi et al., 2024).

Considering the importance of using artificial intelligence in improving efficiency and waste management, this study aims to explore the development of research related to waste sorting and the use of artificial intelligence through a bibliometric analysis approach. It showcases the importance of using VOSviewer analysis in waste management research to identify research topics, identify research trends, and provide direction for future efforts. Bibliometric analysis is used to identify key trends, analyze key relationships, and evaluate the impact of AI on the efficiency, effectiveness, and sustainability of waste management while identifying unexplored research areas and potential research areas that can lead to innovation-based AI. The research questions addressed in this study are: 1) How have organic and inorganic waste-sorting trends evolved globally in recent years? 2) What are the challenges and opportunities in developing and implementing AI-based waste-sorting systems? Therefore, the main objective of this study is to find out the trends in research on waste-sorting and the use of AI in the waste sorting process.

2. METHODOLOGY

This research uses a bibliometric analysis approach to literature related to sorting organic and inorganic waste and using artificial intelligence in waste sorting. This bibliometric analysis is a quantitative method that involves the application of statistics to evaluate the relationship and impact of publications, authors, institutions, and countries in a particular field of research (Fu et al., 2023). The database used in this research originated from Scopus and was exported on February 10, 2024. The data retrieval process is shown in Table 1.

Table 1 shows the data collection process in waste management research. The inclusion criteria in the study only selected journal articles related to waste sorting, recycling, and AI applications. In addition, this selection focused only on English publications classified as “articles” in Scopus. Meanwhile, the exclusion criteria filtered out less relevant sources, such as conference papers, book chapters, review articles, and studies that broadly addressed waste management or AI without specifically addressing waste sorting. These selection processes considerably improved the accuracy of the studies in analyzing AI applications in waste sorting research. Data collection began by pulling data from the Scopus database. A data search was conducted using the keyword “waste”, which yielded 573,104 documents related to waste in general. Then, the search was narrowed to “waste management”, resulting in 69,006 documents. This query was further refined by including the keyword “recycling”, resulting in 14,989 documents. After that, the keywords were restricted to “sorting”, resulting in only 810 documents being identified.

The data was then processed using the bibliometric analysis tools VOSviewer and Biblioshiny to spot research trends, identify key contributors, and visualize networks within the existing literature, providing a basic understanding of how AI has been applied in waste management research. The final stage of the query is integrating AI into the search with the terms "artificial intelligence" or "AI" alongside the previous keywords. The result was only 11 documents, indicating very little research on using AI for waste management, especially in the sorting process. These 11 articles are then analyzed in more detail in the research results.

Table 1. Data collection overview: Waste management research keywords and results

Keywords	Query	Result	Date	Data process
Waste	(TITLE-ABS-KEY (waste)	573,104 documents	10 February 2024	Bibliometric: Vos-viewer Biblioshiny
Waste management	(TITLE-ABS-KEY (waste) AND TITLE-ABS-KEY ("Waste Management")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE"ar"))	69,006 documents		
Recycling	(TITLE-ABS-KEY (waste) AND TITLE-ABS-KEY ("Waste Management") AND TITLE-ABS-KEY (recycling)) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE, "ar"))	14,989 documents		
Sorting	(TITLE-ABS-KEY (waste) AND TITLE-ABS-KEY ("Waste Management") AND TITLE-ABS-KEY (recycling) AND TITLE-ABS-KEY (sorting)) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE, "ar"))	810 documents		
AI OR "ARTIFICIAL INTELLIGENCE"	(TITLE-ABS-KEY (waste) AND TITLE-ABS-KEY ("Waste Management") AND TITLE-ABS-KEY (recycling) AND TITLE-ABS-KEY (sorting) AND TITLE-ABS-KEY (ai OR "ARTIFICIAL INTELLIGENCE")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE, "ar"))	11 documents		Literature

3. RESULTS AND DISCUSSION

3.1 The research trend analysis of waste sorting technology based on annual publication and countries

The bibliometric method was used to analyze waste sorting research trends. First, the research trend is shown based on annual data production. The annual data production was processed using different bibliometric and network analysis programs: Microsoft Excel and VoSViewer. VoSViewer software was used to determine the research trends on organic and inorganic waste sorting technology, and Microsoft Excel was used to visualize the data.

Figure 1 shows the annual scientific article production data for the last 20 years (2003-2023). Based on the data shown in Figure 1, the research trend of organic and inorganic waste sorting from 2003 to 2023 shows significant development. At the beginning of the period, article production tended to be low, even reaching the lowest point in 2003 with no articles produced. However, since 2009, there has been a steady and sharp increase in the last years (2017-2023). This is due to the awareness of the importance of efficient waste management, the demand for environmental sustainability, technological advances in waste sorting, and the changing era of the Industrial Revolution. Despite a slight decrease in 2023, the number of articles produced remains high compared to the beginning of the period, indicating that this topic remains relevant and in demand by researchers in recent years.

In order to explore the data on countries conducting research in this field, this study investigated author countries based on multi-country or single-country collaboration. The most prominent countries in organic and inorganic waste sorting technology are shown in the documents published in each country and the number of citations (Figure 2). China is ranked first, with the highest number of publications and total citations. Denmark is the most dominant country in organic and inorganic waste sorting technology, with 110.80 citations per document. Next is Singapore, with 71.50, and the Netherlands, with 65.10 citations per document.

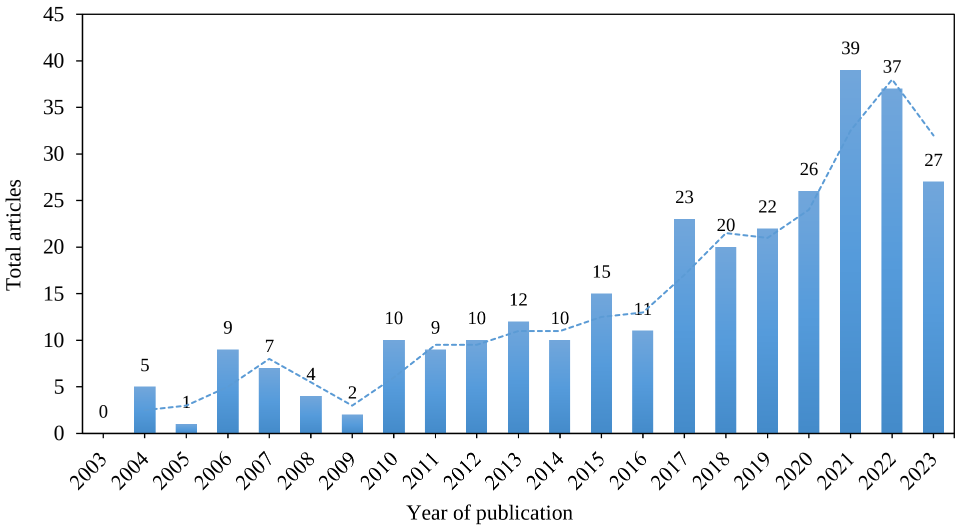

Figure 1. Trends in the number of citations per year 2003-2023

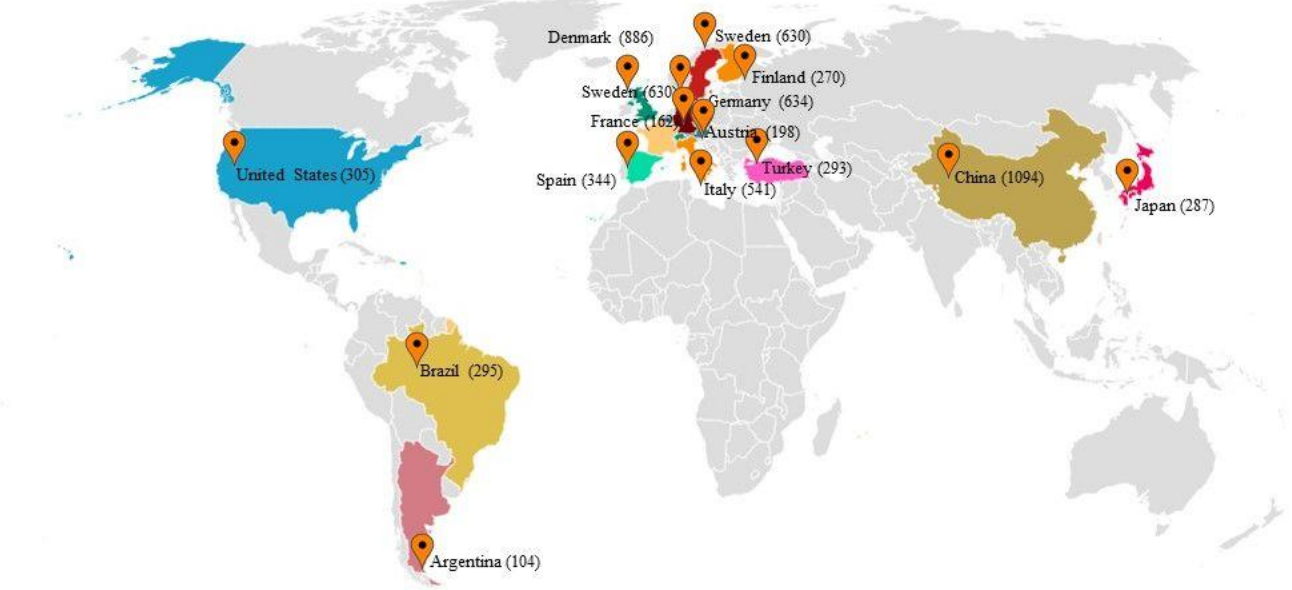

Figure 2. The distribution of countries with highest citation counts in organic and inorganic waste sorting technology research

Figure 2 illustrates the distribution of countries with the highest citations in research on organic and inorganic waste sorting technologies. China leads with 1094 citations, followed by Denmark with 886 citations and Germany with 634 citations. Sweden, the Netherlands, Italy, Spain, the United States, Brazil, and Turkey complete the top 10 list. This data demonstrates the global reach and impact of research efforts in waste sorting technologies, with contributions and recognition coming from countries across continents such as Europe, Asia, and the Americas. However, the detailed country production is shown in Table 2.

Table 2 compares the number of citations and average citations of articles from different countries in waste sorting technology research. China leads with 1,094 total citations but a relatively lower average of 26.70 per article. In contrast, Denmark has fewer citations (886) but a much higher average of 110.80 citations. This indicates the impact and quality of their research output. Other countries include the Netherlands and Singapore, which have relatively high average citations.

3.2 Research trend analysis of leading authors and source of publication

The study found ten of the most influential and prolific authors researching organic and inorganic waste sorting technology. Miezah K's study published in 2015 was the most cited, with 340 citations and an average number of citations per year of 34.0. Similarly, this author published the most recently published article to enter the top 10 most cited articles, (Dahlbo et al., 2017) and (Bernstad, 2014) took second and third place in terms of number of citations, with a total of 222 and 201 citations, respectively, and an average annual number of citations of 31.71 and 18.27, respectively (see Figure 3).

Table 2. Detailed country production information over time

No.	Country	Total citations	Average article citations
1	China	1,094	26.7
2	Denmark	886	110.8
3	Germany	634	25.4
4	Sweden	630	42.0
5	Netherlands	586	65.1
6	Italy	541	33.8
7	Spain	344	49.1
8	Usa	305	27.7
9	Brazil	296	37.0
10	Turkey	293	41.9
11	Japan	287	22.1
12	Finland	270	38.6
13	Belgium	235	21.4
14	Austria	198	14.1
15	France	162	16.2

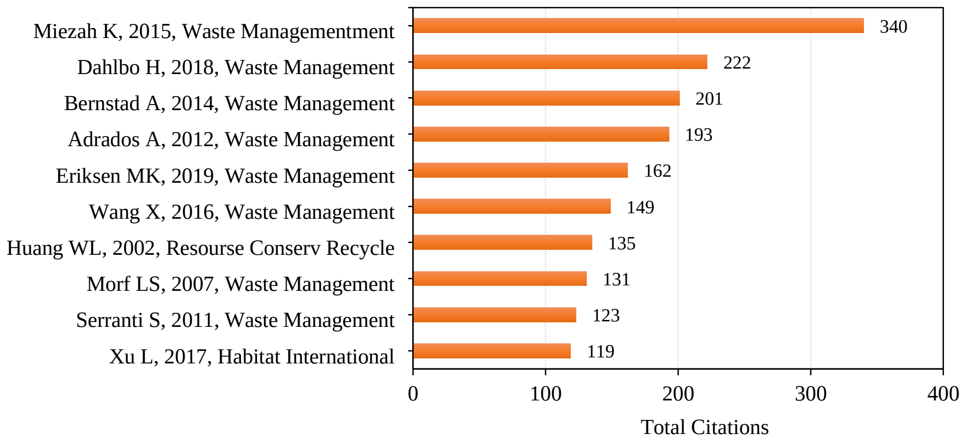

Figure 3. Most global citations based on research on organic and inorganic waste sorting technology

In addition, this research examines the most-published journal data related to research on organic and inorganic waste-sorting technology. It found that the journal with the most published articles was Waste Management (77 articles), followed by Resources, Conservation and Recycling articles and Waste Management and Research articles, with totals of 26 and 22 (see Figure 4).

3.3 Analysis of keywords in research on organic and inorganic waste sorting technology

The most relevant keywords were also analyzed to highlight trending topics and possible future research topics. The research map of organic and inorganic waste-sorting technology articles publishing illustrates the grouping of keywords marked by their color and number of nodes.

The grouping of keywords is categorized by color in Figure 5, and includes sorting and recycling technologies, waste management strategies, and integration of AI and economic principles into sustainable waste management solutions. Cluster 1 (red), consisting of 23 sorting technology items consisting of classification, construction and demolition waste, experimental design, electronic waste, electric charge, electric field, electrostatic process, electrostatic separation, granular materials, image processing, mass balance, particulates, resource recovery, sorting, sorting at source, sorting efficiency, shredding, solid waste management, survey, triboelectricity, waste composition, waste electrical and electronic equipment, and waste sorting.

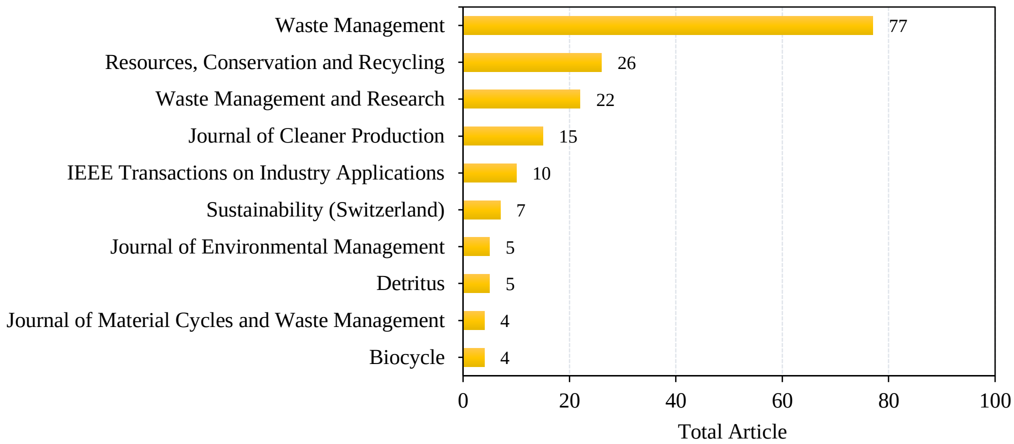

Figure 4. The distribution of published articles in top journals

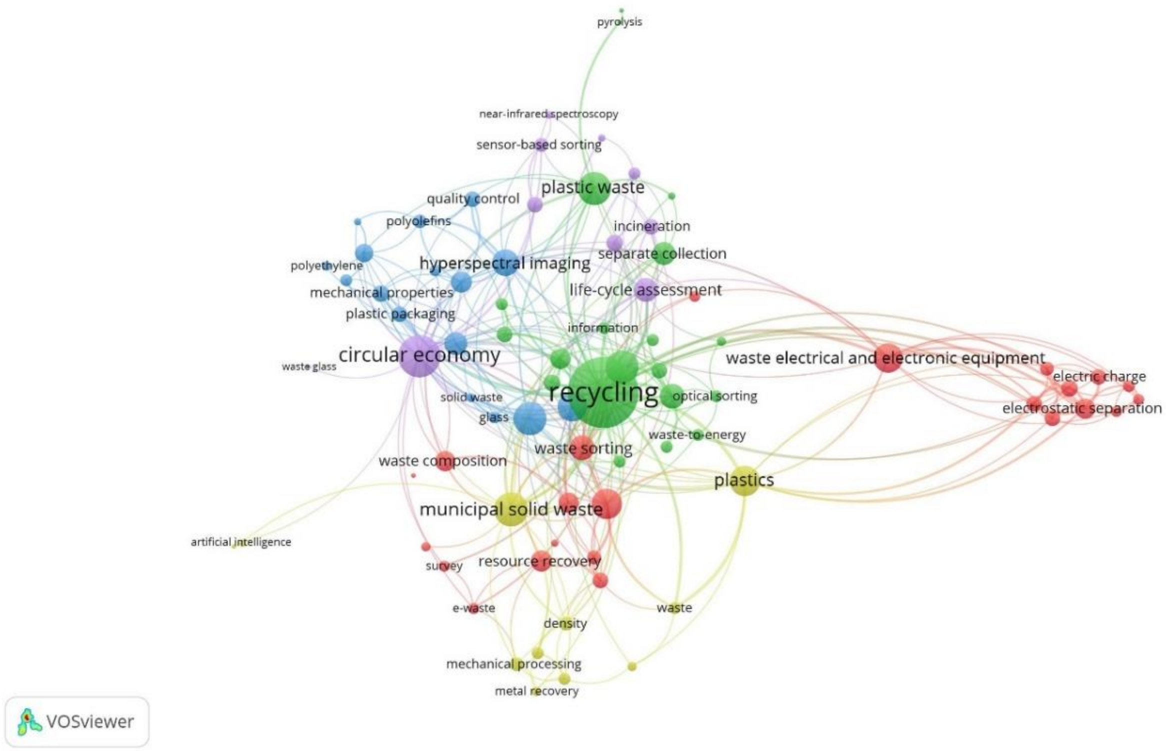

Figure 5. The most relevant keywords related to organic and inorganic waste sorting technology [Source: Data Processing Result-Vosviewer (2024)]

Cluster 2 (green) (green) consists of recycling technologies with 20 items including of China, flotation, food waste, household waste, information, optical sorting, packaging waste, plastic recovery, waste plastics, polymers, pyrolysis, recycling, recycling behavior, separate collection, source separation, sustainability, valorization, waste separation, waste valorization, and waste to energy. Cluster 3 (blue) relates to waste management with 16 items including glass, hyperspectral imaging, material flow analysis, mechanical properties, mechanical recycling, plastic packaging, plastic packaging waste, plastic recycling, polyethylene, polyolefins, post-consumption waste, quality control, recycling, solid waste, waste segregation, and waste management. Cluster 4 (yellow) deals with city solid waste, with 11 items: artificial intelligence, automatic sorting, bottom ash, density, gravity separation, mechanical treatment, metal recovery, metal recycling, municipal solid waste, plastics, and waste. Cluster 5 (purple) is 10 technology-economy items including circular economy, composting, incineration, life cycle assessment, municipal solid waste management, near-infrared spectroscopy, polymer recycling, sensor-based sorting, waste glass, and waste treatment.

As shown in Figure 6, the thematic map was created based on keywords from the authors and mapped into four themes: niche (top left), motor (top right), developing or declining (bottom left), and central (bottom right). In the motor, well-developed research themes are plotted on the top right, including Cluster 1: waste management, waste disposal, municipal solid waste, waste treatment, and solid waste. The basic themes of Cluster 4 include recycling, separation, plastics, plastic recycling, and e-waste. Specific themes include materials such as metals, copper, metal recovery, aluminum, and iron. Emerging or declining themes contain 1 Cluster theme, such as elastomers, electrostatic separators, electronics, electrostatic separation, and polyvinyl chloride.

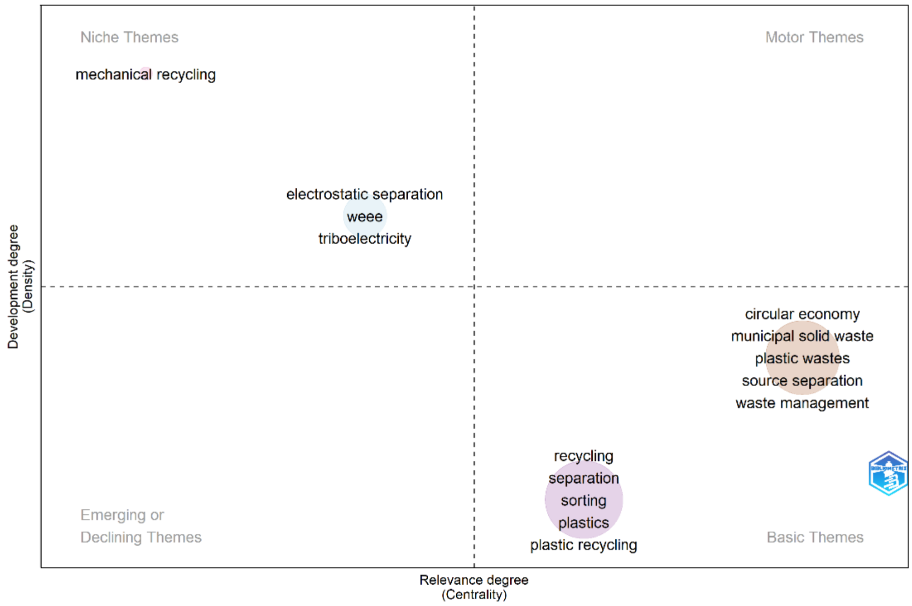

Figure 6. Thematic Map of Authors' Keywords Categorization [Source: Data Processing Result- Biblioshiny (2024)]

Table 3 shows the results of the most relevant literature on integrating artificial intelligence (AI) into waste-sorting technology. The findings show that waste-sorting technology has successfully improved the efficiency and effectiveness of separating organic and inorganic waste. Several research studies have attempted to examine the development and application of advanced AI algorithms in this field. For instance, Liu et al. (2018) have developed an innovative waste sorting system using the SURF-BoW image processing algorithm and Multi-class SVM, which can show improved accuracy in image-based waste sorting. In addition, Chen et al. (2021) and Wang (2022) also tried to use learning techniques to improve the classification and separation of recyclable waste. These findings also show the potential of AI in optimizing the waste management process. The innovations from these studies demonstrate waste segregation and contribute to more sustainable environmental planning and management.

In addition, some studies have also combined AI with other technologies, such as the Internet of Things (IoT), and continue to revolutionize the waste management system. The research of Liao (2022) and Wang et al. (2021) integrated IoT with machine learning and deep learning to create an innovative city waste management system. The system uses real-time data analytics to optimize waste collection routes, monitor waste levels, and improve operational efficiency. In addition, Aroba et al. (2023) and Tandon and Bansal (2023) also examined the application of innovative waste management solutions in smart cities. This demonstrates the transformative impact of AI and IoT in achieving sustainable waste management practices and improving urban living conditions. This literature review shows that AI has also been widely used in waste sorting.

Table 3. The most relevant articles on artificial intelligence integration into waste-sorting technology

No.	Journal title	Author	The role of AI in waste sorting
1	Novel smart waste sorting system based on image processing Algorithms: SURF-BoW and Multi-class SVM	Liu et al. (2018)	Development of an intelligent waste sorting system that uses SURF-BoW and Multi-class SVM image processing algorithms to improve efficiency in the process of image-based waste sorting.
2	Optimization of site selection for construction and demolition waste recycling plant using genetic algorithm	Liu et al. (2019)	Use of AI techniques, in the process of optimizing site selection for construction and demolition waste recycling plants.
3	Artificial intelligence-based e-waste management for environmental planning	Chen et al. (2021)	Application of AI to efficiently manage e-waste, to support more sustainable environmental planning.
4	The adoption of an intelligent waste collection system in a smart city	Aroba et al. (2023)	Implementation of smart waste collection systems in smart cities, which improve the efficiency and effectiveness of waste management through innovative technologies.
5	Intelligent garbage classification system based on deep learning	Liao (2022)	Using deep learning to recognize and separate recyclable waste.
6	IoT-enabled smart city waste management using machine learning analytics	Bakhshi and Ahmed (2018)	Application of Internet of Things (IoT) technology to manage waste in smart cities using machine learning analytics, improving the efficiency of waste collection and processing.
7	A smart IoT system for waste management	Chen et al. (2018)	Implementing a smart waste management system utilizing IoT technology.
8	Research on intelligent garbage classification algorithm based on deep learning	Wang (2022)	Development of deep learning and application of Python in deep learning, and study of intelligent garbage classification algorithms based on Python deep learning.
9	A smart municipal waste management system based on deep-learning and internet of things	Wang et al. (2021)	Combining IoT technology and deep learning to improve waste management efficiency.
10	Waste management system using IoT-based machine learning in university	Khoa et al. (2020)	Optimizing waste collection routes using machine learning techniques.
11	IoT-enabled smart waste management: Leveraging the power of IoT for sustainable solutions	Tandon and Bansal (2023)	IoT-based waste management system can improve the efficiency of waste collection.

The differences between municipal, industrial, and medical waste can affect the accuracy of AI in waste classification and management. For example, AI trained only on municipal waste will have difficulty with accuracy when identifying medical or industrial waste because each type of waste is different. Municipal waste is mixed, industrial waste may contain toxic materials, and medical waste includes syringes and expired medications. In addition, differences in regulations and classification standards can cause AI to classify non-hazardous waste into hazardous waste incorrectly. The technology is also different: computer vision for municipal waste, chemical sensors for industrial waste, and object recognition for medical waste. Therefore, the model must be trained with waste data covering all the above categories for AI to work accurately.

Some future-related research can be developed related to waste management. First, in developing a waste sorting system, AI can improve the accuracy and speed of waste sorting with advanced image recognition and data analysis. In addition, AI can also be used to predict the amount and type of waste generated, which can be used for easier waste management planning and lower operational costs. Secondly, the development of renewable technologies, including the production of bioenergy from organic waste such as biogas and biofuel, and the improvement of the efficiency of of the conversion process should be encouraged. Third, research on the potential size of microorganisms can be developed to help break down various types of organic waste that can be used in waste-conversion technologies. Fourth, multi-disciplinary collaboration on waste management challenges involving scientists, government, industry, and communities to support innovation and investment in waste management technologies.

4. CONCLUSION

The findings of this study show that the trend of research on organic and inorganic waste sorting technology is growing significantly. This indicates that interest in this research is relatively high. This research found that China is the most productive country, based on the number of citations. However, most of the other productive countries are in Europe, making it the continent with the most countries contributing to waste management research. Then, regarding authors, Miezah K's research, published in 2015, was the most cited. Meanwhile, the journal that published the most articles was Waste Management Journal, followed by Resources, Conservation and Recycling, and Waste Management and Research Journal. A literature analysis of the most relevant articles showed that integrating artificial intelligence (AI) into waste-sorting technology can improve the efficiency and effectiveness of sorting organic and inorganic waste and contribute to sustainable environmental planning.

In the future, research and applications related to organic and inorganic waste sorting technology research can be one of the efforts to minimize waste. In addition, research on organic and inorganic waste sorting technology is fundamental to solving environmental problems. This research is the basis for developing new scientific research questions. It is recommended that researchers pursue the development of AI-enabled waste sorting technology, refine the sorting processes, and carry out a thorough impact study. These researchers should also strengthen collaboration with international colleagues and publish in well-known journals so that their output has more impact. Policymakers must put more effort into establishing regulatory standards, funding research, and promoting sorting technologies in industries and cities. Launching educational training and establishing joint efforts with the private sector are also important to hasten the introduction of better and more sustainable waste-sorting technologies.

ACKNOWLEDGEMENTS

Conceptualization, Mahliza Nasution and Muhammad Irwansyah, Hermansyah; Methodology, Mahliza Nasution; Software, Mahliza Nasution; Validation, Mahliza Nasution, Muhammad Irwansyah; Formal Analysis, Mahliza Nasution; Investigation, Mahliza Nasution; Resources, Mahliza Nasution; Data Curation, Mahliza Nasution; Writing - Original Draft Preparation, Mahliza Nasution and Rospita Gultom; Writing - Review and Editing, Mahliza Nasution and Rospita Gultom; Visualization, Mahliza Nasution; Supervision, Muhammad Irwansyah; Project Administration, Rospita Gultom; Funding Acquisition, Mahliza Nasution, Muhammad Irwansyah and Hermansyah.

DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest.

REFERENCES

Arisona RD. 3R (reduce, reuse, recycle) waste management in social studies learning to foster environmental care character. Al Ulya: Journal of Islamic Education 2018;3(1):39-51 (in Indonesian).

Aroba OJ, Xulu T, Msani NN, Mohlakoana TT, Ndlovu EE, Mthethwa SM. The adoption of an intelligent waste collection system in a smart city. Proceedings of the Conference on Information Communications Technology and Society (ICTAS); 2023 Mar 8-9; Durban: South Africa; 2023.

Aulia DC, Situmorang HK, Prasetya AFH, Fadilla A, Nisa AS, Khoirunnisa A, et al. Improving community knowledge and awareness on waste management with *Jepapah* messages. Journal of Community Health Service 2021;1(1):62-70 (in Indonesian).

Bakhshi T, Ahmed M. IoT-enabled smart city waste management using machine learning analytics. Proceedings of the 2nd International Conference on Energy Conservation and Efficiency (ICECE); 2018 Oct 26-27; UET Lahore: Pakistan; 2018.

Bernstad A. Household food waste separation behavior and the importance of convenience. Waste Management 2014; 34(7):1317-23.

Chen J, Huang S, BalaMurugan S, Tamizharasi GS. Artificial intelligence-based e-waste management for environmental planning. Environmental Impact Assessment Review 2021; 87:Article No. 106498.

Chen WE, Wang YH, Huang PC, Huang YY, Tsai MY. A smart IoT system for waste management. Proceedings 1st International Cognitive Cities Conference (IC3); 2018 Aug 7-9; Okinawa: Japan; 2018.

Dahlbo H, Poliakova V, Mylläri V, Sahimaa O, Anderson R. Recycling potential of post-consumer plastic packaging waste in Finland. Waste Management 2017;71:52-61.

Djawad YA, Suhaeb S, Muhtar MA. Improving community knowledge and awareness on waste management with *Jepapah* Messages. Journal of Telecommunication and Computer Electronics 2022;17(1):1-11 (in Indonesian).

Dzakiya N, Kiswiranti D, Hidayah RA, Muchlis. Utilization of organic and an-organic waste in Sedayu Village, Muntilan District. Journal of Dharma Bakti 2019;2(2):184-90 (in Indonesian).

Febriadi I. Utilization of organic and inorganic waste to support go green concept at school. Abdimas: Papua Journal of Community Service 2019;1(1):32-9.

Fu Y, Mao Y, Jiang S, Luo S, Chen X, Xiao W. A bibliometric analysis of systematic reviews and meta-analyses in ophthalmology. Frontiers in Medicine 2023;10:Article No.1135592.

Harjanti IM, Anggraini P. Waste management in Jatibarang Landfill, Semarang City. Journal of Planology 2020; 17(2):185-97 (in Indonesian).

Junaidi J, Utama AA. Analysis of waste management with the 3R principles (Reduce, Reuse, Recycle) (Case study in Mamak

Village, Sumbawa Regency). Journal of Social Science and Education 2023;7(1):Article No. 4509 (in Indonesian).

Khoa TA, Phuc CH, Lam PD, Nhu LMB, Trong NM, Phuong NTH, et al. Waste management system using IoT-based machine learning in University. Wireless Communications and Mobile Computing 2020;2020(1):Article No. 6138637.

Liao Q. Intelligent garbage classification system based on deep learning. Proceedings of the 4th International Conference on Intelligent Control, Measurement and Signal Processing (ICMSP); 2022 Jul 8-10; Hangjhou: China; 2022.

Liu J, Xiao Y, Wang D, Pang Y. Optimization of site selection for construction and demolition waste recycling plant using genetic algorithm. Neural Computing and Applications 2019;31:233-45.

Liu Y, Fung K-C, Ding W, Guo H, Qu T, Xiao C. Novel smart waste sorting system based on image processing algorithms: SURF-BoW and multi-class SVM. Computer and Information Science 2018;11(3):Article No. 35.

Nurdin A, Lidiawati M, Khairi NF. The effect of organic, inorganic and hazardous and toxic waste (B3) on health in workers at the Gampong Jawa Landfill in Banda Aceh City. Journal of Aceh Medika 2020;4(2):113-21 (in Indonesian).

Rahmatullah I. Training on the implementation of plastic waste sorting at SDN 001 Samarinda Utara. Mahakam Journal of Educational Creativity 2023;3(1):124-6 (in Indonesian).

Rekabi S, Sazvar Z, Goodarzian F. A bi-objective sustainable vehicle routing optimization model for solid waste networks with internet of things. Supply Chain Analytics 2024;5:Article No. 100059.

Siagian I, Tambunan N, Hatmoko BD, Aulia HN. Community service program of waste bank of cooperative residents association Jonggol District, Bogor Regency. Journal of Community Service 2022;1(12):3457-66 (in Indonesian).

Tandon R, Bansal A. IoT-enabled smart waste management: Leveraging the power of IoT for sustainable solutions. Proceedings of the 3rd International Conference on Innovative Sustainable Computational Technologies (CISCT); 2023 Sep 8-9; Dehradun: India; 2023.

Wang C, Qin J, Qu C, Ran X, Liu C, Chen B. A smart municipal waste management system based on deep-learning and Internet of Things. Waste Management 2021;135:20-9.

Wang X. Research on intelligent garbage classification algorithm based on deep learning. Proceedings of the International Conference on Artificial Intelligence, Information Processing and Cloud Computing (AIIPCC); 2022 June 21-23; Kunming: China; 2022.

Wibysono AY, Susilawati H, Matin IMM. Design of raspberry pi-based organic and non-organic waste sorting tool. Journal of FUSE Electrical Engineering 2022;2(2):88-96 (in Indonesian).

Zhu Y, Jia G, Han G, Zhou Z, Guizani M. An NB-IoT-based smart trash can system for improved health in smart cities. Proceedings of the 15th International Wireless Communications and Mobile Computing Conference (IWCMC); 2019 Jun 24-28; Tangier: Morroco; 2019.