



Trends in integrated waste management research: A content analysis

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Abstract

Analyze the trends that characterize scientific production through textual statistics and text mining methods, highlighting the most debated topics useful for developing new research perspectives in this field. Textual statistics and text mining methods were chosen to analyse the real scope of integrated waste management, focus the investigation on the central elements of their discussion, and the trends that characterized scientific production in that field. Two argumentative dimensions that characterize the corpus, the one with the greatest response, in terms of quotation, is aspects with 48 extracted quotations. This result indicates how scientific research focuses more on the relationship between integrated waste management and waste treatment, recycling, disposal, and environmental. The analysis made it possible to define the most debated issues in integrated waste management clearly. From an elements point of view, integrating waste management depends on the treatment, recycling, and disposal.

Keywords :

Integrated waste management, text mining, textual statistics, waste treatment

1 Introduction

Waste management and recycling are neither new concepts nor new activities (Ribić et al., 2017). Materials had been recycled long before the term was coined in the twentieth century (Grosse, 2010). People have always seen value in items cast-off by others. Witness the aphorism that "one's trash is another man's treasure". Historically, waste management has been inextricably linked with the evolution of human communities, population growth, and commerce's emergence and development (Hussain et al., 2022). During the past century, consumption and production patterns have changed radically due to the greater freedom of movement of money, goods, and people (Wiedmann et al., 2020).

The philosophy of the "Waste Management Hierarchy" (prevention/minimization, materials recovery, incineration, and landfill) has been adopted by most industrialized nations as the menu for developing sustainability waste management strategies (Hemidat et al., 2022). Any option used within a given country (or region) varies depending on many factors, including topography, population density, transportation infrastructures, socioeconomics, and environmental regulations (Sakai et al., 1996). Moreover, comparing national waste statistics is not a simple task.

Consideration must first be given to the widely different administrative definitions applied to sustainability waste management (Ferronato and Torretta, 2019). In addition, compositional classifications and how the data are collected also differ (Abdel-Shafy and Mansour, 2018). Collectively, these factors can have a significant influence on the cited data.

However, these reviews analyzed a limited number of papers. For this reason, using the methodology of text mining, this work aims to adopt a broader approach, which takes into consideration most of the scientific production in the integrated waste management - without distinction of sectors, types of organizations, or specific aspects of the phenomenon - analyzing trends, underlining the most debate topics, to develop new pathways for future research in integrated waste management.

2 Material and methods

2.1 Data collection

According to Feldman and Sanger (Feldman and Sanger, 2006), data collection is represented by processes to identify a corpus related to the topic to be analyzed. We used the SCOPUS database, one of the largest abstract and citation databases for academic literature. Thanks to the database functions, it was possible to select the types of contributions, such as articles, reviews, and conference papers, and the reference period selected from 1995 to today.

Preliminarily, the query with the term 'Integrated Waste Management' was used, which resulted in 362 documents. Subject ar-

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eas were also added to achieve a corpus of 259 documents that could be numerically significant and, at the same time, qualitatively centered with the subject of investigation. Table 1 shows the steps and queries applied for the search.

Therefore, a dataset was created containing the abstract, author's keywords, and source of each article. It was also possible to download each contribution to creating the corpus to apply the methods for this analysis.

Table 1 Queries on scopus database – March 2022

Keywords	Boolean noperator	Subject areas	No. documents
Query 1 Integrated Waste Management	-	-	326
Query 2 Integrated Waste Management	-	Environmental Science	259

2.2 Overview of articles

Over the considered period (1995–2022), the number of published researches shows a growing trend, the annual average of 9 published articles (Figure 1).

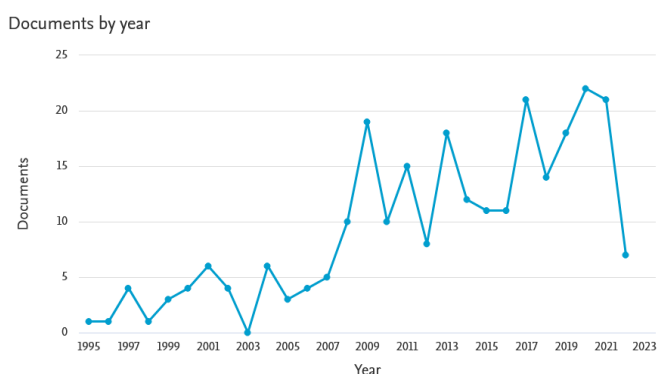


Figure 1 Scientific production on integrated waste management (1995–2022)

An overview of the journals in which the selected articles were published shows a correspondence between the corpus and the object of investigation since they all deal with clean production, waste management, environmental issues, sustainability, and recycling (Figure 2).

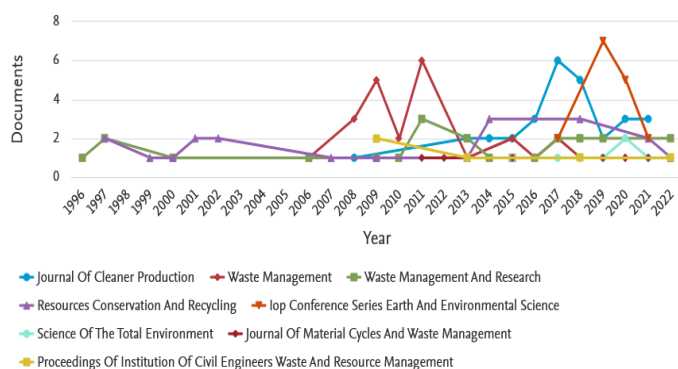


Figure 2 Scientific production by source

2.3 Textual analysis method

The methodologies used in this work were textual statistics and text mining methods. These methods were chosen to analyze the

real scope of integrated waste management, focus the investigation on the central elements of their discussion, and the trends that characterized scientific production in that field. Textual statistics is the mathematical study of texts meant as a collection of distinct items that can be compared by analyzing their frequency (Lebart et al., 1998). It is widely used, especially in linguistic research (Kosmajac and Keselj, 2020; Savoy, 2010), and it employs a variety of methods, ranging from procedural processing, in which the texts are not exposed to any prior analysis, to cases in which linguistic knowledge can be used to classify textual types with precise meaning (Melissourgou and Frantzi, 2017).

The first step of this study was to analyze the frequencies of the author's keywords in the selected corpus. The analysis has been carried out with ATLAS.ti (Friese, 2019; Hwang, 2007), a data analysis software for qualitative research that allows to carry out various investigations on the data constituting the corpus showing in a graphic form the properties and relationships between the information to give meaning and structure to the data. All keywords with a frequency higher than 4 have been categorized into two different argumentative dimensions (Table 2).

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Table 2 Keywords categories

Argumentative dimensions	Keywords
Elements	Generation, separation, collection, transfer, transport, treatment, disposal, reduction, reuse, recycling, recovery
Aspects	Technical, environmental, health, financial, economic, social, cultural, institutional, policy, legal, political

The second phase of the study investigated the elements that characterize scientific output related to integrated waste management. The method chosen for this analysis was text mining (Kontostathis et al., 2010). It is possible to explore and analyze vast volumes of textual data to define themes, templates, and other attributes. According to Feldman and Sanger (Feldman and Sanger, 2006), the use of text mining to probe documents includes three distinct phases:

1. Constitution of corpus;
2. Pre-processing and cleaning;
3. Review and assessment of information.

At this stage, some information contained in the corpus may be irrelevant for the analysis (Cegan et al., 2017). For this reason, pre-processing and cleaning phase removes from the corpus all the insignificant words that commonly appear in the language, such as prepositions, conjunctions, pronouns, and punctuation. It was also necessary to clean up data from the characteristic terms of scientific articles, such as 'journal', 'review', 'paper', and 'DOI'.

According to Bazeley (Bazeley, 2013), the argumentative dimensions and the relative keywords (Table 2) have been used to code the corpus. Coding is a basic ability for qualitative research because it offers access to evidence that can be used to question results, verify hypotheses, and draw conclusions. At the most basic level, naming a code creates a mark that connects data to the concept and the idea to all the data relating to that idea (Richards and Morse, 2012). The codification of the articles in the corpus allowed us to extract all sentences that contained those words from it. An analysis of co-occurrence codes (Canzonetti, 2010; Scharp, 2021) was carried out for each argumentative dimension to highlight the codes applied to the same quotation and determine which topics are mentioned simultaneously and how often. This approach allows to analyze the trend topics of a very high number of papers concerning integrated waste management, but at the same time,

thanks to the analysis of the co-occurrence tables, to address the analysis towards the study of specific aspects of interest.

In this case, the next phase was represented by analyzing the quotations extracted selecting the pair of codes with the highest frequency. To visualize the results, we chose the Word Clouds approach. This representation style is utilized in various scenarios to summarize the most commonly occurring terms in a text. For example, Moro et al. (Moro et al., 2019) used this methodology to determine the scope of the literature and define the notion of ethnic marketing, which is characterized by considerable heterogeneity. Other applications can be found in the biomedical field and the rapidly growing big data and computer science (Sinclair and Cardew-Hall, 2007). It is also defined as a useful summary for determining the amount and type of subjects present in a body of text (Steele and Iliinsky, 2010; Kuo et al., 2007), and it is obtained by positively correlating the font size of the represented words with its frequency in the text.

3 Results and discussion

In the following literature analysis, we selected the corpus of over 98.174 words, which was analyzed using the ATLAS.ti software. For each argumentative dimension, it was possible to establish the main topics covered and give a selection of the most representative articles on topics results. It was also possible to choose minimum threshold values, excluding words less frequently used and focusing attention on the most used words. What derives from this is a clear sign of the most discussed issues in every single dimension.

3.1 Argumentative dimension of elements

Figure 3 relates to the argumentative dimension of elements.



Figure 3 Elements argumentative dimension word cloud

The relationship between recycling, treatment, and disposal on element variables is clear. All three are important elements in integrated waste management. Treatment in waste management refers to the activities required to ensure that the waste has the least practical impact on the environment (Wan et al., 2019). In many countries, various forms of treatment in waste management are required by law (LaGrega et al., 2010). In practice, the treatment process in waste management includes several techniques, including biological, recycling, mechanical, mechanical biological, and thermal (Rhyner et al., 2017; de Sadeleer et al., 2020; Havukainen et al., 2017; Fei et al., 2018; Malinauskaitė et al., 2017). While recycling is one part of the treatment of waste management in waste processing to prevent waste that can be useful, reducing the use of new raw materials, reducing energy use, reducing pollution, land damage, and greenhouse gas emissions (Zorpas, 2020). The results in the waste treatment process that cannot be

recycled will end up at disposal (Vo Dong et al., 2018). In the abstracted scientific article, the implementation of integrated waste management is strongly influenced by these three elements. Table 3 explains about frequencies of word cloud in an argumentative dimension of elements.

Table 3 Application word cloud – frequencies of elements argumentative dimensions

Word	Frequencies
Recycling	477
Treatment	436
Disposal	412
Recovery	249
Generation	146
Collection	120
Reduction	106
Separation	68
Transport	52
Reuse	49
Transfer	30

3.2 Argumentative dimension of aspects

Figure 4 relates to the argumentative dimension of aspects. The topics most treated are related to the aspects dimension is environmental. The environment is important in integrated waste management because the impacts resulting from the waste processing process will cause ecological, social, economic, and aesthetic problems.



Figure 4 Aspects argumentative dimension word cloud

The environment is a natural, artificial, and social system that affects the continuity of life and welfare of humans and other living things (Jean-Louis et al., 2016; Sandifer et al., 2015). Therefore, the existence of the environment must be considered in every management of human activity, including waste management, because the environment is a system in which there is an embodiment of a place where there is human interest in it (Naser, 2021; Corris, 2020).

One of the environmentally friendly waste management is an integrated effort to preserve environmental functions, which includes policies for structuring, utilizing, developing, maintaining, recovering, monitoring, and controlling the environment (Palilinan et al., 2019).

That environmentally sound waste management can be carried out with the principles of responsibility, sustainability, and benefit principles aimed at realizing environmentally friendly sustainable development in the context of human development for the future (Alayón et al., 2017; Mensah, 2019).

Table 4 explains about frequencies of word cloud in the argumentative dimension of aspects.

Table 4 Application word cloud – frequencies of aspects argumentative dimensions

Word	Frequencies
Environmental	776
Economic	228
Policy	134
Health	107
Social	77
Financial	49
Technical	40
Institutional	18
Legal	12
Political	9
Cultural	5

3.3 Research trends

The text mining approach for the analysis of integrated waste management research allowed us to build a helpful framework for in-depth investigations in this field. The definition of argumentative dimensions based on the author's keywords allowed the coding of the corpus and the construction of co-occurrence tables useful for tracing the trends and identifying connections between all the defined topics, and developing new research perspectives in this research field.

Of the two argumentative dimensions that characterize the corpus, the one with the greatest response, in terms of quotation, is aspects with 48 extracted quotations. This result indicates how scientific research focuses more on the relationship between integrated waste management and waste treatment, recycling, disposal, and environmental. However, the other topics receive less attention.

In the corpus of over 250 scientific papers, the main indication is represented by aspect dimension. This result highlights how technical, environmental, health, financial, social, cultural, institutional, policy, legal, and political aspects appear to be of great interest to researchers in this field.

4 Conclusions

The analysis made it possible to define the most debated issues in integrated waste management clearly. From an elements point of view, integrating waste management depends on the treatment, recycling, and disposal. Meanwhile, from the aspect point of view, what affects integrated waste management is the environment. This study achieved the objective of providing a picture of the current research in integrated waste management, testing a valuable research tool for subsequent more detailed analyses and debates on this research topic.

Declaration of competing interest

The authors declare no known competing interests that could have influenced the work reported in this paper.

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