Towards sustainability in waste management: a systematic literature review

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Abstract

Sustainable waste management is undoubtedly an important topic requiring in-depth research and consideration. Due to a growing number of publications on the subject, there is a need to systematically review the literature on sustainable waste management to identify and evaluate the recorded works. A systematic review of 6,734 academic articles published since 2010 was conducted. The final dataset of 144 articles was classified into twelve subjects: published year, context, geographical region, location, funding, type of waste, sector analyzed, data source, main subjects, methods, results, and period analyzed. The results show that the amount of literature on sustainable waste management was three times higher since 2015 compared to the previous period and in poorer countries, which are facing more environmental concerns than developed countries. A majority of reviewed articles focus on Asia and urban areas. Solid waste holds the attention of most selected studies. The highest portion of the selected research uses case study methodology and primary data. The research gap and limitations pointed out in the study provide practical suggestions for researchers seeking to contribute to sustainable waste management.

Keywords: Waste management, Environmental sustainability, Systematic review

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1. Introduction

With the rising prosperity of humanity, the amount of waste generated daily is striking as a profound global concern, especially when a great proportion of which is not efficiently managed. The world generates 2.01 billion tonnes of municipal solid waste every year, at least 33% of which is not environmentally friendly (World Bank, 2018). The amount of waste is expected to increase to 3.40 billion tonnes by 2050, implying a severe problem that affects every aspect of human life.

Many researchers have pointed out the negative impacts of improper waste management practices. From the environmental perspective, waste in general and waste that is inappropriately handled can lead to air pollution, water pollution, and land pollution. Solid waste-related emissions would reach approximately 2.6 billion tons of CO_2 by 2050 (World Bank, 2018). Along with air pollution, improper waste management methods lead to contaminated groundwater (Skenderovic *et al.*, 2015) and ocean plastic pollution (Lestari and Trihadiningrum, 2019). This is consequently followed by soil pollution since the deterioration of land quality is often caused by uncontrolled liquid waste and sewage disposal (Ashraf *et al.*, 2014).

Apart from environmental problems, related issues would also arise due to low priority for waste management. The most vulnerable communities directly affected by poor waste disposal systems are laborers who earn their living from salvaging and sorting waste. Exposure to parasites and intestinal infections from mishandled waste would critically affect the health condition of that group, and hence, induce the escalation of several health issues associated with waste disposal (Giusti, 2009; Alam and Ahmade, 2013).

The economy as well cannot bear the consequences of ineffective waste disposal systems. Improperly handled waste in the short term directly affects the tourism and hospitality industry due to the degradation of landscapes and tourist attractions (Zorpas *et al.*, 2015). In the long term, the decomposition of waste by conventional and inappropriate methods creates sagging areas, where buildings and other facilities cannot be constructed, which is enormous destruction to the economy (Skenderovic *et al.*, 2015).

Sustainable waste management can serve as a solution to the mentioned problems caused by improper waste disposal. When sustainably handled, waste can be utilized as a vital resource concerning the considerable amount of energy that can be recycled and produced from solid waste (Demirbas, 2011). Furthermore, waste-to-energy, also known as energy recovery, conserves resources and supports environmental and human protection through the process of converting waste into sources of fuel (Brunner and Rechberger, 2015).

Under the sustainable development perspective, properly adopted waste management has proven its irreplaceable role in shaping environmental protection and promoting the efficient use of resources (Izvercian and Ivascu, 2015). The United Nations (2019) latest updates on the Sustainable Development Goals define, for example, Goal 12 as the urgent need to implement practices that increase resource efficiency and reduce waste among every

sector of the economy, and Goal 13 as a call for all countries to tackle cleaner and more resilient economies under such challenging contexts brought by constantly changing weather patterns, extreme natural events, incessantly rising sea levels, and greenhouse gas emission. Since sustainable waste management ensures the reduction of waste and pollutants and the conservation of resources through the reprocessing of waste and conversion to energy, it is intertwined with the achievement of many sustainable development goals.

Every country has its own waste management policies, which may constantly change, depending on the amount of waste production and contamination. In China, a series of laws were promulgated, providing a legal framework for the protection of the environment, namely the Environmental Protection Law enacted in 1989, the first legislation enforced in 2005 and the first law of Urban Construction Waste and Construction Dregs Regulation pertaining to Construction and Demolition Waste Management (CDWM) enforced in 2003. Moreover, in different cities in China, existing CDWM policies have been reported under the 3Rs treatment in terms of financial studies (Aslam *et al.*, 2020). In the USA, waste management legislation was much earlier promulgated, among which Solid Waste Disposal Act enacted in 1965, Resource Conservation and Recovery Act in 1976. Especially, most of the states in this country have their own regulations and surveillance setups for handling construction and demolition waste (Aslam *et al.*, 2020). In developing countries, waste management is a major concern due to existing inadequate and ineffective practices. In Vietnam, there is a distinction among cities. Although many waste management policies have been issued in Hanoi, implementation and mechanism and guiding documents are still lacking, leading to inefficient implementation. Waste management in Da Nang City is weaker than that of Hanoi and Ho Chi Minh City as waste collection, transportation, and treatment are not well managed, collection price is low and state authority is not responsible (Tsai *et al.*, 2020).

Admittedly, some review articles are appertaining sustainable waste management in the currently available source of literature. However, prior review research mainly focuses on limited and scattered aspects of sustainable waste management, such as reviews on a specific framework, policy or technology, or evaluation of a distinctive type of waste management practices. There is hardly any previous synthetic literature review providing an overview and analysis of past and present sustainable waste management research.

There is a need to develop a wide-based body of research about sustainable waste management, evaluate the recorded works produced by researchers, practitioners, and scholars, and then identify key areas in which more information is needed. This paper provides a systematic literature review on sustainable waste management. The study can help regulators, policy-makers, and researchers with a better understanding of current sustainable waste management and changes over time. It may also be of value to practitioners and environmentalists who often rely on research-based evidence to support their claims. We developed the analysis and methodology of this study to investigate the following research questions: *What are the general trends in sustainable waste management literature? What*

are the research gaps and limitations? What are the recommendations for future studies on sustainable waste management?

The paper is organized as follows. First, the authors provide an overview of sustainable waste management. Next, we address methods used to systematically review the literature on sustainable waste management. We then present the findings, point out the research limitations, and finally discuss further research on sustainable waste management that can be developed.

2. An overview on sustainable waste management

2.1 Waste management concept

The concept of waste management has been interpreted in different ways. The European Council (1991) defines waste management as the control of operations and after-care practices towards waste conducted by disposal sites, including collection, transport, recovery, and disposal. According to Pongracz *et al.* (2004), waste management involves the supervision of all waste-related activities to conserve resources as well as protect human health and the environment. Bacinschi *et al.* (2010) describe waste management as a process of collecting all thrown-away materials for recycling and minimizing their negative effects on health, life quality, and the surrounding environment. Demirbas (2011) defines waste management as the collection, transport, processing, recycling, disposal, and monitoring of waste, to encourage the reuse of materials and hinder the number of resources that enter and leave the society, heading for healthful and uncontaminated living conditions. Despite the varying differences, all the mentioned definitions share the same traits describing waste management as the activity of dealing with waste to ensure human and environmental protection.

2.2 Waste management hierarchy

The waste management hierarchy is considered as guidelines for waste management, categorizing various waste management options from the most to the least environmentally favorable ones. Waste management hierarchy serves as the primary principle, shaping the waste management concept, with prevention ranked as the most preferred option and disposal as the least favored one (El Haggar, 2010). The hierarchy has been interpreted and practically applied in different ways under various circumstances, thus is now a widely accepted foundation for waste management practices (Ferrari *et al.*, 2016).

The waste management hierarchy proffers that different and specific waste management strategies would vary greatly depending on the changing context (Ferrari *et al.*, 2016). The hierarchy also sets a path for the categorization of the waste management methods presented in the next part of the paper.
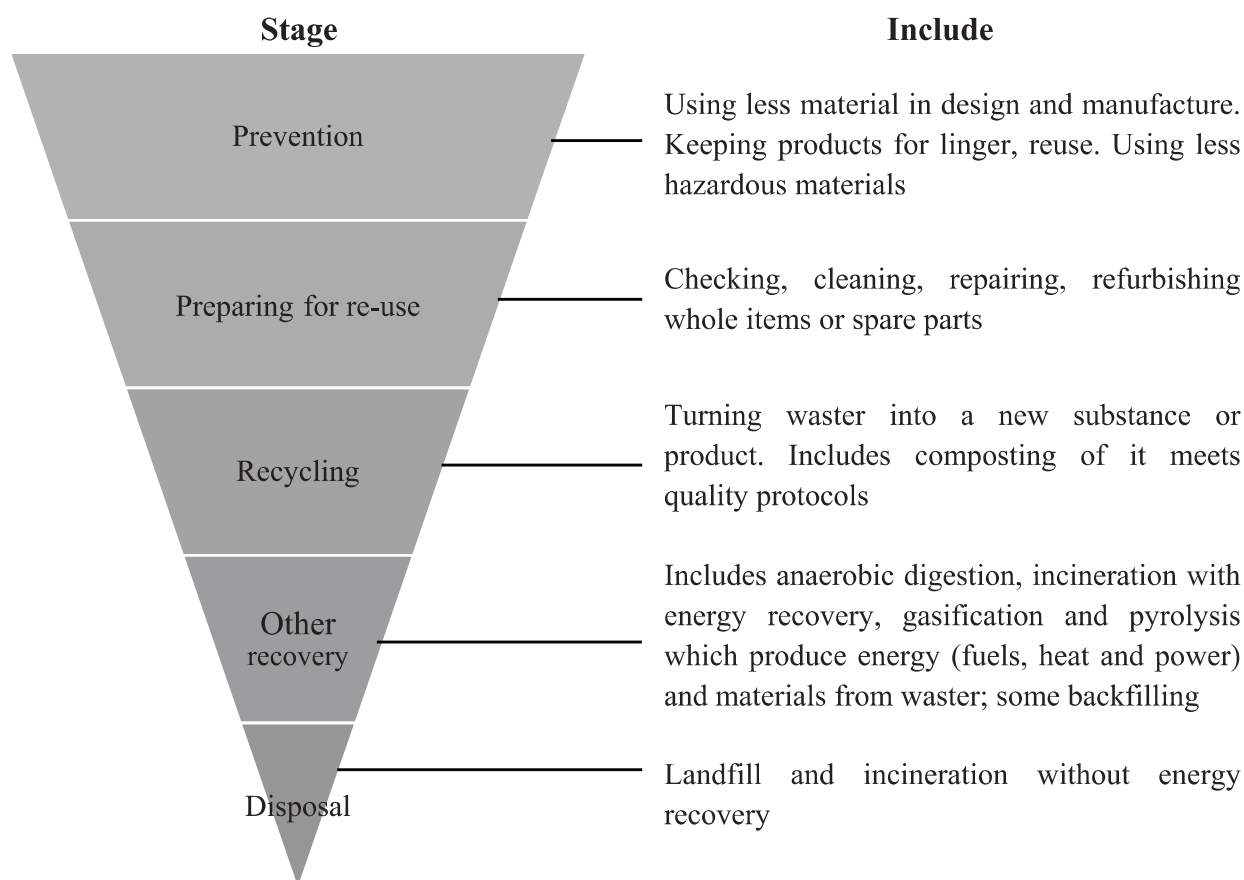
Stage		Include

Prevention — Using less material in design and manufacture. Keeping products for linger, reuse. Using less hazardous materials

Preparing for re-use — Checking, cleaning, repairing, refurbishing whole items or spare parts

Recycling — Turning waster into a new substance or product. Includes composting of it meets quality protocols

Other recovery — Includes anaerobic digestion, incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat and power) and materials from waster; some backfilling

Disposal — Landfill and incineration without energy recovery

Figure 1. Waste management hierarchy

Source: European Commission (2011)

2.3 Sustainable waste management

In the context of sustainable development, the waste management concept must be understood from an inseparable perspective to the United Nations Sustainable Development Goals (SDGs) to fully understand, thoroughly analyze and critically evaluate the available research on this subject of matter.

Several articles have confirmed the goals and roles of waste management in relation to accomplishing the UN SDGs. Muralikrishna and Manickam (2017) determine economy, environment, and social community as three fundamental factors of sustainable development. They state that economic growth deals with satisfying what people want without conceding the quality of life, especially in a developing world; social development involves the protection of people's health from pollution or other damaging business activities; and environmental protection considers the need to preserve the surrounding environment. Environmental protection is the most vital pillar of sustainable development, interacting with the other two to ensure humanity's future. This interconnection among the three fundamentals can be perceived in the attempt to encourage businesses to keep their carbon emission below a certain level and promote the responsible use of natural resources in the economic sector, and the consistent

efforts to improve awareness and legislation in the social sector, all intimately disclosed to the principle of waste management.
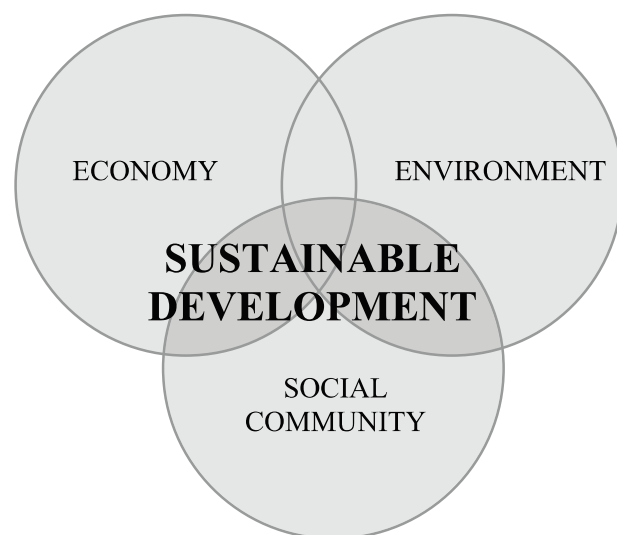

Figure 2. Three pillars of sustainable development

Source: Muralikrishna and Manickam (2017)

Dermatas (2017) confirms that the most compelling environmental issues targeted in the UN SDGs are also addressed in waste management. Particularly, sustainable waste management can resolve the problem of soil and groundwater pollution as well as the future shortage of non-renewable resources, which are evidently articulated by SDG 6 (clean water and sanitation) and SDGs 11 to 15 (sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land). In a broader context, sustainable waste management intricately relates to the provision of cleaner and safer living conditions around the world, distinctively tackled by the first 4 SDGs (no poverty, zero hunger, good health and well being, quality education). Goal 7 (affordable and clean energy) can be achieved through in determination of landfill waste proportion during the waste categorization process to further utilize them in producing more modern, reliable, affordable, and sustainable sources of energy (Dada and Mbohwa, 2018). In brief, the international acceleration to sustainable waste management and comprehensive movement towards circular economy depends heavily on the awareness promotion launched by the ongoing SDG procedures and campaigns (Hettiarachchi, 2019).

3. Methodology

3.1 Literature search

The literature search was performed firstly by formulating research questions and identifying keywords. Research questions were developed after careful consideration of the research rationale in the contemporary contexts. Searching keywords were then specified directly from the established research questions, based on the theoretical reference with regards to the two concepts of waste management and sustainable development. The searching terms were ultimately determined as "waste management" and "sustainable development".

The searching strategy was conducted on the official websites of seven worldwide prestigious academic publishers: Elsevier, Nature, Inderscience, Sage, Taylor & Francis Group, Springer, and Wiley. We selected the advanced searching tools available on each publisher's official websites to look for research and review papers with keywords in title, abstract, or author biography, with English designated as the language of publication. This initial searching step resulted in 6,734 articles.

3.2 Screening criteria

The results from the first search produced a wide range of articles. To ensure the selected studies cover accurate subjects and claim their findings based on valid evidence, we established a set of criteria for inclusion and exclusion and applied them throughout the screening process. In order to select a vast majority of academic papers, we earned the support from Zotero software which has a word processor plugin to integrate directly with LibreOffice. The main screening criteria adopted in this study are presented in Table 1.

Table 1. Screening criteria

Inclusion criteria	Type
Term *waste management* in titles	Content
Published from 2010 to the present	Publication date
Research language: English	Publication language
Journals of prestigious publishers	Journal
Term *waste management* and *sustainable development* or *sustainability* in title, abstract or author-specified keywords	Content
Focus on waste management and sustainable development	Content
Research, review articles	Research design
Exclusion criteria	**Type**
Letters, editorials, books, others	Research design
Articles that mainly focus on other subjects and minorly deal with sustainable development or waste management	Content
Studies aiming to take sustainable development as an evidence to support a new framework, technology, measure or policy that does not directly relate to waste management	Content

Source: The authors' compilation

Practical screening criteria

The first screen sorts out approximately 6,800 results of relevant studies in terms of publication period and covered topics. In this practical screen, the search was limited to papers that were published from 2010 to 2020. The reason for choosing this analysis period revolves around the adoption of the UN SDGs in 2015 since this time range marks a decade of formulating, developing, and approaching the SDGs. We believe the careful observation of

a ten-year period, consisting of five years before and after the adoption of SDGs, will reflect interesting insights into how the event has influenced the trend, numbers, and characteristics of studies on sustainable waste management.

The application of practical screening criteria resulted in 158 potentially usable research from seven famous publishers from 2010 to 2020, with a certain degree of accuracy, efficiency, and relevance.

Quality screening criteria

The final screening assesses 158 papers that satisfy all practical screening criteria to evaluate their relevance, quality, and reliability and identify the best studies to include in the present research.

In this step, we scanned through all articles separately and reported every relevant characteristic in tables, including their titles, authors, affiliations, published years, citations, funding, countries, locations, problems concerned, research questions, data descriptions, data sources, methodology, results and findings, limitations. The adherence to justified quality standards singles out appropriate studies for the current review and requires in-depth reading as well as advanced analysis of all papers. Next, each paper was evaluated individually and studies with invalid contents to be excluded. Some significant-quality screening steps conducted are: overall assessment, validity and reliability check, citation index record, coherence and consistency check, and a scan for limitations.

The next step revolves around comparing presented problems, questions, and objectives of each research with its reported findings and conclusions to assess the usefulness, relevance, and quality of all research results. In other words, research results should consistently provide answers to the research questions previously formulated. Finally, we recorded limitations and research gaps of all studies separately to examine whether they seriously affect the reliability and validity of the study or not and to serve the discussion on prospects for future research on sustainable waste management.
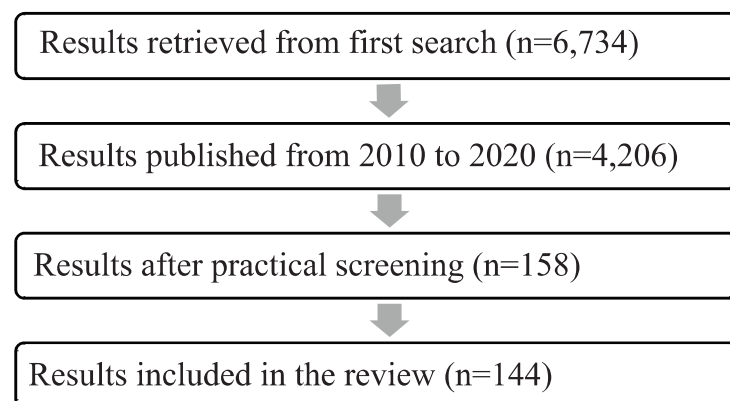
Results retrieved from first search (n=6,734)

⬇

Results published from 2010 to 2020 (n=4,206)

⬇

Results after practical screening (n=158)

⬇

Results included in the review (n=144)

Figure 3. Literature search and screening process

Source: The authors' compilation

Table 2. Number of articles retrieved from selected publishers

Publishers	Results retrieved from the first search	Results published from 2010-2020	Results after practical screening	Results included in the review
Elsevier	3005	1586	68	66
Inderscience	178	149	11	10
Nature	460	431	1	0
Sage	356	291	23	21
Springer	367	322	47	39
Taylor & Francis Group	592	332	5	5
Wiley	1776	1095	3	3
Total	6734	4206	158	144

Source: The authors' compilation

Coding scheme

Based on references to the procedures presented by previously mentioned literature (Fazzo *et al.*, 2017; Ardoin *et al.*, 2018, Stern *et al.*, 2014), we considered the specific objectives, focus, and characteristics of the present research review and developed the coding scheme with categories and subcategories applied throughout this paper for analysis and further discussion. The order and numbering of selected articles were reported in Table 3, along with citation indexes recorded until 28 March 2020. All categories presented in the coding process would follow such order and remain applicable to every section of the current research.

As mentioned, the classification and coding were conducted based on the data collected from in-depth reading and analysis of all selected articles individually to provide an overall and simplified perspective on the available research on sustainable waste management. The classification consists of twelve subjects, numbered from 1 to 12: published year, context, geographical region, location, funding, type of waste, sector analyzed, data source, main subjects, methods, results, and period analyzed. Each of these subjects includes different subcategories coded from A to L, except for the Funding* category whose alphabetical codes were combined with number 0 and 1. A study can receive more than one code due to meeting two or more categorizations.

Table 3. Categories and subcategories

	Meaning	Codes for alternatives
1	*Published Year*	A - From 2010 to 2014
		B - From 2015 to 2020
2	*Context*	A - Developed countries
		B - Developing countries
		C - Non-applicable

Table 3. Categories and subcategories *(continued)*

	Meaning	**Codes for alternatives**
3	*Geographic Region*	A - Africa
		B - Asia
		C - Australia
		D - Europe
		E - America
		F - Non-applicable
4	*Location*	A - Urban area
		B - Rural area
		C - Suburban area
		D - Industrial area
		E - Non-applicable
5	*Funding*	1 - Funded
		0 - Not Funded
	Funding*	A0 - Before 2015, not funded
		A1 - Before 2015, funded
		B0 - From 2015, not funded
		B1 - From 2015, funded
6	*Type of waste*	A - Solid waste
		B - Liquid waste
		C - Organic waste
		D - Recyclable waste
		E - Hazardous waste
		F - Non-applicable
7	*Sector analyzed*	A - Public sector
		B - Private sector
		C - Non-profit sector
		D - Households
		E - Industrial sector
		F - NGOs
		G - Waste management sector
		H - Non-applicable
8	*Data source*	A - Primary data
		B - Previous studies
		C - Reports, publications, database, and training materials

Table 3. Categories and subcategories *(continued)*

	Meaning	Codes for alternatives
9	*Main subjects*	A - Alternatives of sustainable waste management
		B - Evaluation of current methods/situation
		C - Explanations of current problems/situation
		D - Future perspectives on sustainable waste management
		E - Influential factors to sustainable waste management
		F - Impacts of sustainable waste management
		G - Suggestions/solutions/strategies for improvement
		H - Non-applicable
10	*Methods*	A - Archival
		B - Case study
		C - Comparative
		D - Conceptual
		E - Empirical
		F - Experiment
		G - Interview
		H - Life cycle assessment
		I - Observation
		J - Survey
		K - Review
		L - Non-applicable
11	*Results*	A - Consistent with previous studies
		B - Proposal of new frameworks/concepts/strategies/models
		C - Previous concepts/models/frameworks with new perspectives
		D - Previous perspectives with new dataset/time period
		E - Non-applicable
12	*Period Analyzed*	A - Less than 3 years
		B - From 3 to 5 years
		C - From 5 to 10 years
		D - From 10 years
		E - Non-applicable

Source: The authors' calculation

The first classification refers to the year of publication of the articles, coded by letters A and B. The concern of this category revolves around the influences of the adoption of UN SDGs in 2015 on the number, trends, and characteristics of research on sustainable waste management. We divided the observed period into two subcategories: 2010-2014 and 2015-2020. With

five years from 2010 to 2014, the review attempts to look into the status of sustainable waste management study under the existence of the Millennium Development Goals (MDGs) in their last years of legitimation and point out the progress and differences in the next five years period, from 2015, when SDGs was officially adopted.

The second classification is coded by letters A, B, and C. Context is of great importance in research since it provides an understanding of the research question aligned to real-world circumstances, gives meaning to and shapes the research design. Notably, sustainable development and waste management topic can result in huge gaps. Thus, there exists a need to classify contexts based on the terminology currently accepted worldwide, in this case as developed and developing countries. When an article does not conform to those two codes, the non-applicable category is applied. For example, studies that focus on developing countries in general without specifying any certain countries or studies analyzing the topic in countries under political and geographical conflicts would be listed as non-applicable.

For the third classification, the authors established codes from A to F based on geographical concepts of the contemporary world, serving as a complement to the context categorization in providing more specific information on geographical location. The combination of recorded information on geographical region and implications on development forms irreplaceable support in drawing interpretation on the trend influenced by the contextual background of available research.

Location is classified with codes from A to E. When it comes to sustainable development and waste management, the location must not be left out, considering its profound influences on the conditions, facilities, and level of awareness in the studied areas.

The fifth classification in the coding scheme is funding, with number 1 for funded and 0 for non-funded research. This was then combined with the information on published year (before and after 2015) to formulate the following codes: A0, A1, B0, B1. In the present research, we direct the analysis towards the number of funded studies on sustainable waste management overall during the observed period, and more specifically, on the trend and the changes resulted from the adoption of UN SDGs in 2015.

Types of waste were classified with letters from A to F. The types of waste investigated by each paper affect the subject matters, the scope of study, and would also guide the research questions. Therefore, the need to have them systematically sorted out cannot be underestimated. This is followed by sector analyzed, coded by letters from A to H to create a full complement between two categories in shaping the research scope, detecting and verifying the social sectors targeted by every single study included in this review.

The identification of the sources for data collection in all reviewed articles was then addressed by the eighth classification, data source, with codes A, B, and C. The data sources presented in each article can vary from primary data collected by authors; secondary raw data from reports, publications, training materials of certain organizations or authorities, with a low level of relevance to the purposes of the research examined; to secondary data from previous research with the relatively similar matters of concern of scope of the study.

The ninth classification, known as main subjects, was coded with letters from A to H. This classification intends to determine the sub-topics making implications on the trend and focus of published literature on the main topic and find out the subjects most commonly studied by researchers.

The results are coded by letters from A to E, focusing on the results and findings of the reviewed research individually to examine whether the study comes up with new framework/ perspectives or supports existing ones with new data. By analyzing the results, the relevance and quality of each study regarding research questions and problems can be assessed.

The last classification in the coding scheme deals with period analysis, coded with letters from A to E, attempting to analyze the scope of research relating to the period investigated by papers selected for the present studies. The results obtained from this classification complements the context (second) and geographical region (third) classifications to fully assess the depth and breadth of all the reviewed articles.

4. Research results and discussion

4.1 Sample description

One hundred forty-four selected articles were published by six out of seven chosen publishers on top journals in waste and environmental management: 66 articles (46%) were published by Elsevier, 39 articles (27%) were published by Springer, 21 articles (15%) were published by Sage, 10 articles (7%) were published by Inderscience and 8 other articles (5%) were published by Wiley and Taylor & Francis Group.

Table 4. Top journals*

Top journals	Coverage	H-index	Number of publications from 2010-2020
Journal of Cleaner Production	1993 - ongoing	150	57
International Journal of Environment and Waste Management	2008 - ongoing	15	25
Scientific Reports	2011 - ongoing	149	20
Waste Management and Research	1979, 1983 - ongoing	66	15
Environmental Science and Pollution Research	1994 - ongoing	82	9
Journal of the Air and Waste Management Association	1987 - ongoing	89	10
Journal of Sustainable Development	1993 - ongoing	51	

Source: The authors' calculation

4.2 The adoption of the UN SDGs on the amount of sustainable waste management literature

Published year

Out of 144 articles, the majority (74.3%) was published after 2014 (Category B) and the smaller proportion (25.7%) was in the previous period (Category A). This portion is equivalent to 107 articles from 2015 to 2020 and 37 from 2010 to 2014. The result for Category B is three times higher than that for Category A, proving that the number of research that satisfies all the practical and quality criteria and pertinently focuses on sustainable waste management has increased drastically from 2015.

Figure 4. Published year of studies reviewed

Notes: Category A - from 2010 to 2014; B - from 2015 to 2020.

Source: The authors' calculation

A causal association between the 17 UN SDGs adoption and the rise in research on the topic can be reasonably formulated, indicating that after the 17 SDGs came into effect in 2015, the number of articles on sustainable waste management has become considerably higher.

Funding

The second finding in this review concerns the funding status of the analyzed papers. This classification first examines the number of funded papers through the coding of number 1 for funded and 0 for non-funded ones.

The review recorded 79 non-funded and 65 funded papers out of the selected 144 articles. The number of funded research accounts for a slightly lower proportion compared to those that are non-funded. As previously mentioned, we further extended this classification into a broader compound categorization with an attempt to tackle the effects of the UN SDGs adoption in 2015. The complement of this funding classification to the first classification (Published year) resulted in the application of the following codes: A0 - before 2015, not

funded; A1- before 2015, funded; B0 - from 2015, not funded and B1 - from 2015, funded. The results recorded for this supplementary classification are illustrated in Figure 6.
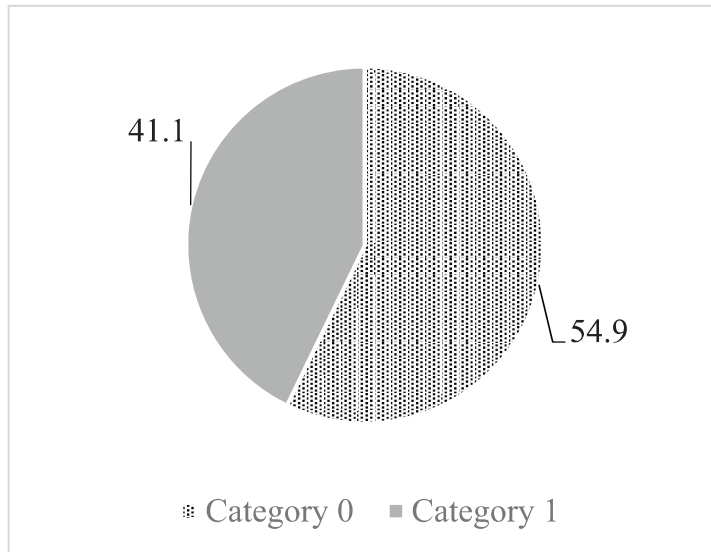

Figure 5. Funding status of studies reviewed

Notes: Category 0 - Non-funded; 1 - Funded.

Source: The authors' calculation

In general, both funded and non-funded research evidently rose since 2015. Although the number of non-funded studies is still relatively higher than those funded ones, the gap is not significant. The number of non-funded research before 2015 (Category A0) is 21 and from 2015 (Category B0) is 58, implying a 2.8-time increase while the number of funded research escalated 3.1 times from 16 (Category A1) to 49 (Category B1) in the same period. The number of funded articles is smaller. However, it seems to increase with a slightly higher speed than the non-funded one.

Figure 6. Funding status of studies reviewed with regards to years of publication

Source: The authors' calculation

Besides, most research fundings recorded come from the public sector. Around 80% of the funded studies in this review received financial supports from governmental authorities such as the Ministry of Environment in their country, the national grant, the public universities or the national research institutes. Also, funded research reported a decent citation index. However, non-funded ones did not present lower results on citations. Therefore, the funding status of research does not seem to severely affect the its degree of being influential.

4.3 Scope of research

Context, geographical region and location

More than half of the selected research (62.5%) investigate sustainable waste management in developing countries suggesting that the topic is being addressed more often in poorer and less prosperous countries which face a lot of environmental concerns. Meanwhile, only 22% chose developed countries as their focus of analysis. The number of studies addressing the subject in developed countries only makes up to one-third of the studies concentrating on sustainable waste management. There are 17 papers examining the matter in both contexts, while five studies did not specify the countries of analysis or did not apply the same measure regarding the scope of research.

Although the sources of financial grants towards the subject are more likely to come from developed countries, more research concerns the associated problems in less developed ones. The economy might still struggle to meet certain development standards and basic living demands before enhancing its waste management systems. Cucchiella *et al.* (2015) report that approximately 50% of the waste electric and electronic equipment generated annually was illegally transferred from developed to developing countries, resulting in serious environmental problems. Improper waste handling happens more often in developing countries since infrastructures, legislation and frameworks for sustainable waste management is still absent (Ferronato and Torretta, 2019).
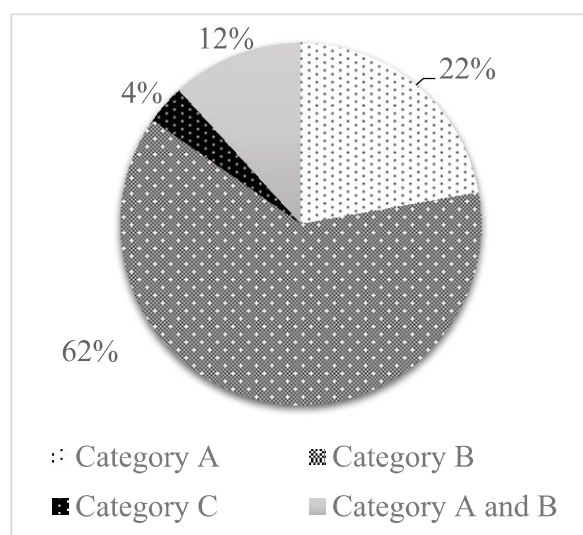

Figure 7. Context of studies reviewed

Notes: Category A - from 2010 to 2014; B - from 2015 to 2020

Source: The authors' calculation

The following classification deals with the geographic region analyzed by the studies. We noticed that a considerable number of studies do not involve only one but rather several different countries. Since some of the reviewed articles focus on more than one region, there are few code combinations.

The greatest proportion of the articles investigated the subject in the context of Asia, followed by 26% of the articles demonstrating their concern in the context of Europe, 10% of the articles demonstrating their concern in the context of America, and 9% of the articles demonstrating their concern in the context of Africa. Only 1% of the reviewed articles focus on sustainable waste management in Australia. Around 4% of the articles analyzed the topic in two or more geographical regions. The rest (6%) of the paper is not applicable to the coding scheme developed for this paper. Remarkably, the amount of research investigating sustainable waste management in Asia increased significantly in the latter five years compared with that in the prior period implying that waste management became a greater concern for most developing countries in this continent.

Figure 8. The geographical region of studies reviewed

Notes: Category A - Africa; B - Asia; C - Australia; D - Europe; E - America; F - Non-applicable.

Source: The authors' calculation

This phenomenon is, however, foreseeable, considering the distinctive social and geographical features of these two continents. Meanwhile, in the case of Africa, sustainable waste management might not receive much attention presently since the priority is being set on more fundamental and concerning issues associated with basic life demands. The focus of scholars and policy-makers regarding this geographical region, therefore, is often put on solving poverty, clean water inadequacy or diseases, rather than sustainable waste management.

The classification of location describes the specific area of the researched countries indicated in the reviewed articles, coded by a letter from A to E. The combination of subcategories also applies to this classification due to the similar reason stated above.
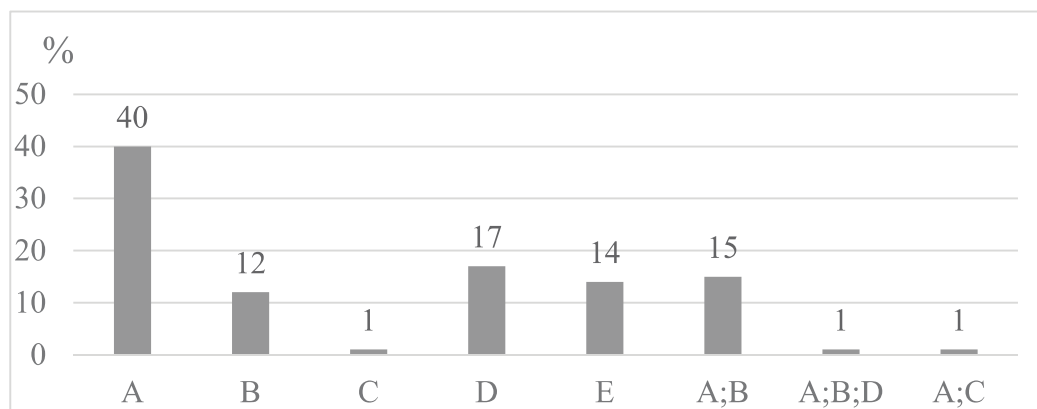
Figure 9. Location of studies reviewed

Notes: Category A - Urban area; B - Rural area; C - Suburban area; D - Industrial area; E - Non-applicable.

Source: The authors' calculation

Out of 144 papers selected for the review, 58 direct their analysis towards sustainable waste management in urban areas, accounting for 40% of the articles and the largest portion recorded for this classification. About 17% of the articles, which is equivalent to 25 research, address the matter in industrial areas. About 12% of the articles is about the rural areas and 14% of them are categorized as non-applicable. There is only one article (1%) about suburban areas. The other 17% of the articles concentrate on more than one areas, in which 21 research (15%) focus on both urban and rural areas. One article (1%) is about the urban and industrial area and another one article is about (1%) three areas: urban, rural, and industrial.
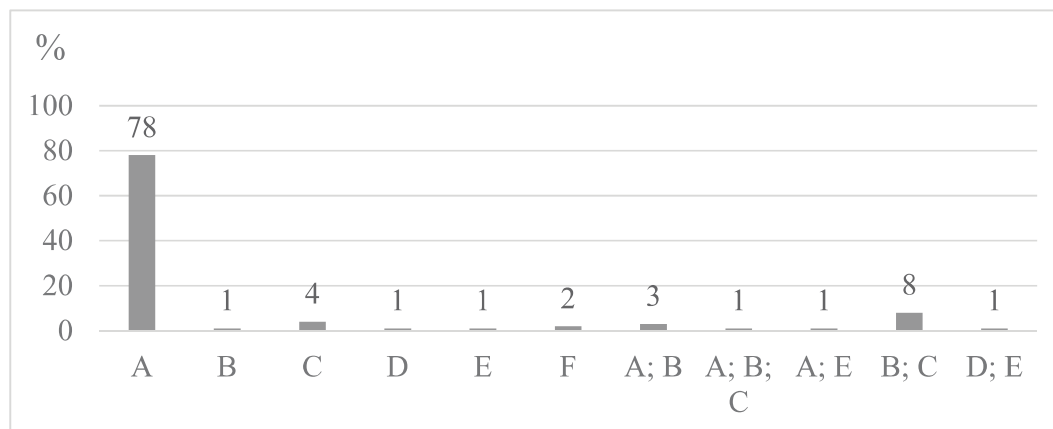
Types of waste

Figure 10. Types of waste in studies reviewed

Notes: Category A - Solid waste; B - Liquid waste; C - Organic waste; D - Recyclable waste; E - Hazardous waste; F - Non-applicable.

Source: The authors' calculation

A huge gap between the portion of research addressing solid waste (Category A) and the other types of waste can be observed from the chart below. The great majority of articles revolves around solid waste, accounting for 78% of the total amount and evenly distributed in the 2010-2014 and 2015-2020 periods. Nine studies are scattered among liquid, organic, recyclable, hazardous waste (Category B, C, D, E), equivalent to 7%. About 14% of the reviewed research (21 papers) scrutinized in more than one type of waste and the last 2% are reported as non-applicable (Category F).

Solid waste holds the attention of most selected studies, leaving very few spaces for other types of waste. Conceivably, solid waste is the most concerning current issue to researchers, scholars, and policy-makers, suggesting that this type of waste is probably more complex compared to others in certain aspects, such as composition, classification or handling methods.

Sector analyzed

The public sector was investigated in 28% of the total research. Many papers were found to research waste management in the private sector, and incredibly few for non-governmental (Permana *et al.*, 2015; Takiguchi, 2016; Kamaruddin *et al.*, 2013) and non-profit sector (Kruljac, 2012; Shumon *et al.*, 2014). We accordingly suspect that the public sector is more responsible for the quality and improvement of waste management systems and, therefore, should be more bonded to take action through policy and procedure adjustments.
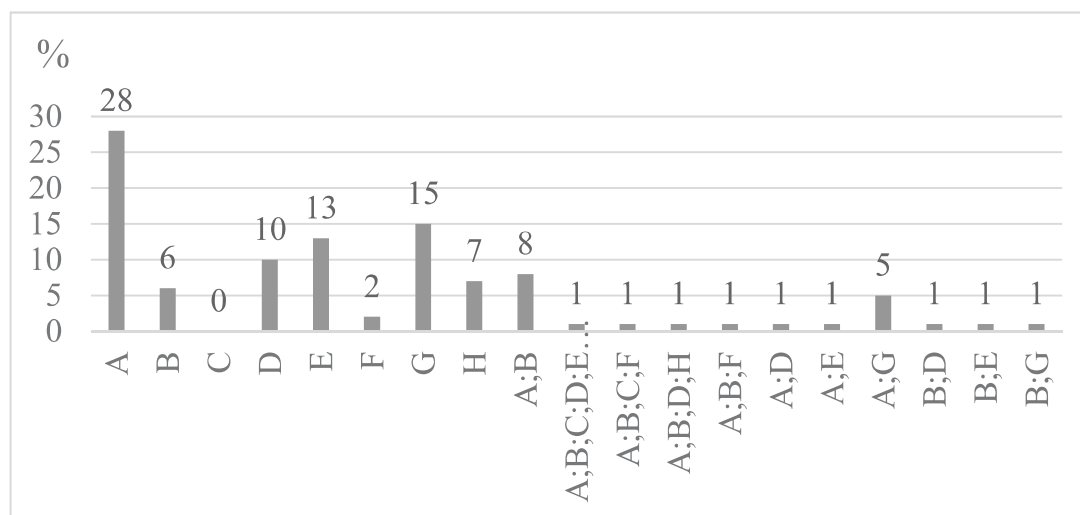

Figure 11. Sector analyzed of studies reviewed

Notes: Category A - Public sector; B - Private sector; C - Non-profit sector; D - Households; E - Industrial sectors; F - NGOs; G - Waste management sector; H - Non-applicable.

Source: The authors' calculation

Waste management sector (Category G) was examined in 15% of all articles (21 studies) and ranks as the second most common sector tackled by the reviewed articles, followed by industrial sector (Category E – 18 studies which account for 13% of all articles), households (Category D – 14 studies which account for 13% of all articles) and private sector (Category

B – nine studies which account for 6% of all articles). Category F, NGOs, was investigated in only 2% of all articles, which is equivalent to three papers. The non-applicable, Category H, holds with ten research. Noticeably, a considerable proportion of the selected research, 22%, analyzed several different types of waste in the same paper, most of which include either solid waste or liquid waste or both in their focus of analysis.

Analysis period

The last classification relating to the scope of research deals with length of the period targeted in the papers. The subcategories for this classification are coded as: A - less than 3 years; B - from 3 to 5 years; C - from 5 to 10 years; D - from 10 years and E - non-applicable.

About 24.3% of all papers, which is equivalent to 35 studies, examine the period of more than 10 years. About 20.9% of the articles, which is equivalent to 30 studies, investigate a period of fewer than three years. The number of research analyzing a more than three and less than ten years period accounts for 20.1% of total papers. About 9.7% of which investigate a period from 3 to 5 years and the other 10.4% of all papers examine a period from 5 to 10 years. There are 50 articles in the non-applicable subcategory, taking up to 34.7% of all papers, which is the largest portion of the selected research.
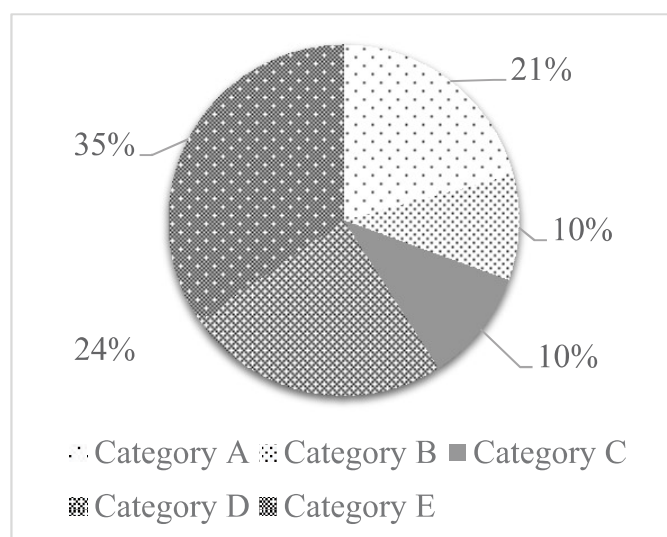

Figure 12. Analysis period of studies reviewed

Notes: Category: A - less than 3 years; B - from 3 to 5 years; C - from 5 to 10 years; D - from 10 years; E - Non-applicable.

Source: The authors' calculation

Main subjects

The classification of main subjects identifies the sub-topics coded by: A - Alternatives of sustainable waste management; B - Evaluation of current methods/ situation; C - Explanations of current problems/situation; D - Future perspectives of sustainable waste management;

E - Influential factors to sustainable waste management; F - Impacts of sustainable waste management; G - Suggestions/solutions/strategies for improvement and H - Non-applicable.

The majority of the reviewed papers (58%) oriented their analysis to one single main subject, which is specified in 83 out of 144 articles. The number of articles with two or more sub-topics accounts for 28% of all papers. There are 20 review articles listed in the non-applicable category for not meeting any subcategories developed in the coding scheme.
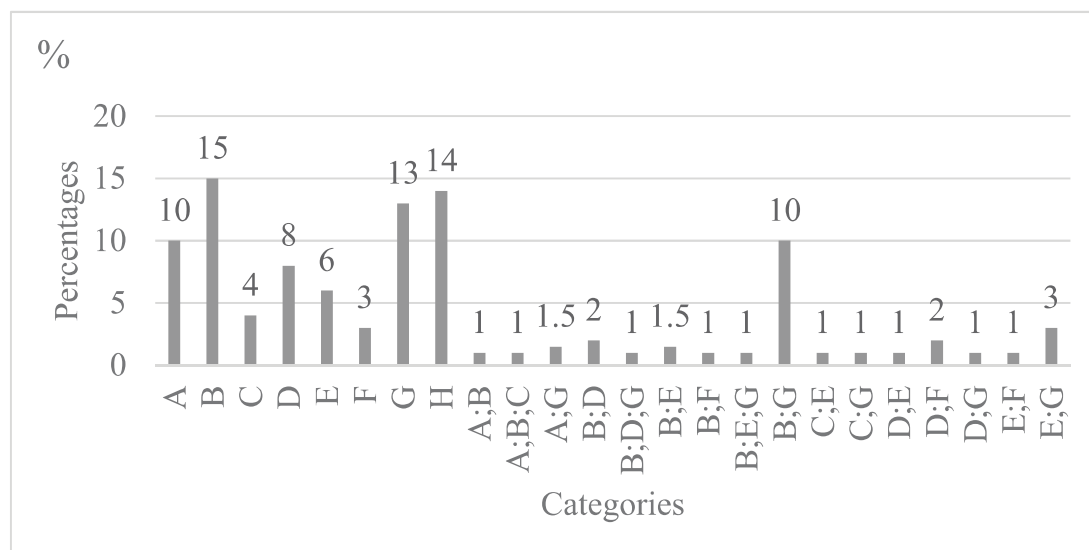

Figure 13. Main subjects of studies reviewed

Notes: Category A - Alternatives of Sustainable Waste Management; B - Evaluation of current methods/situation; C - Explanations of current problems/situation; D - Future perspectives of sustainable waste management; E - Influential factors to sustainable waste management; F - Impacts of sustainable waste management; G - Suggestions/solutions/strategies for improvement; H - Non-applicable.

Source: The authors' calculation

Of all the research that concentrates on solely one main subject, the three most significant results recorded are 15% for Category B, 13% for Category G and 10% for Category A. The other categories appear in smaller quantity: 8% for Category D, 6% for Category E, 4% for Category C, and 3% for Category F.

Since Categories B and G strike with the highest results among single-subjected articles, not surprisingly, the most common code combinations recorded belongs to Category B;G (combination of evaluation of the current methods/situation and suggestions/solutions/ strategies for improvement), with 15 out of 41 research with more than one subject of focus, accounts for 10% of the total included articles. The other combinations received relatively insignificant results with 1-2% of all papers, which is equal to less than three papers for each category.

4.4 Methods

In general, the reviewed articles were distributed evenly among the methodology coded in this research, which is easily observed from no differences in the results recorded for each category. The greatest number of research falls on Category B (case study), with 43 articles accounting for 20% of all articles. Since case study is frequently adopted in exploratory research to test or investigate a new idea, perspectives, theory or framework within their real-life context (Mcleod, 2015), the prevalence of this methodology in sustainable waste management study can be justified by the novelty of the subject. As stated, sustainable waste management is a relatively new topic, with the growing need for experiment and disclosure of new yet realistic and practical angles to decently understand its boundary and complexity. Consequently, an in-depth case study of particular groups and events over periods is often considered an effective and favorable method for approaching such underlying principles of the topic in a real-life context.

The methodology with second highest frequency reported is Category J (Survey), with 34 studies (15%), which is followed by Category A (Archival) and Category D (Conceptual), both with 49 research, equivalent to 11% for each category. The next category reflects the interview method with 22 studies (10%).

Categories with lower frequency recorded are H, I, and J, with 14 studies in each category. Altogether, they account for 18% of the reviewed papers. Category C receives only 5% of the total articles, Category F comes after with eight papers and Category E ranks as the least with only four articles. Also, 3% of the reviewed studies use uncategorized methods as one of their methodology for analysis and research designs, which is equivalent to seven papers.

A significant proportion of the reviewed papers uses more than one method to approach and analyze their research matter. Therefore, the present study also tackles the number of such studies, aiming for some implications on the trends in methodology of the current research.
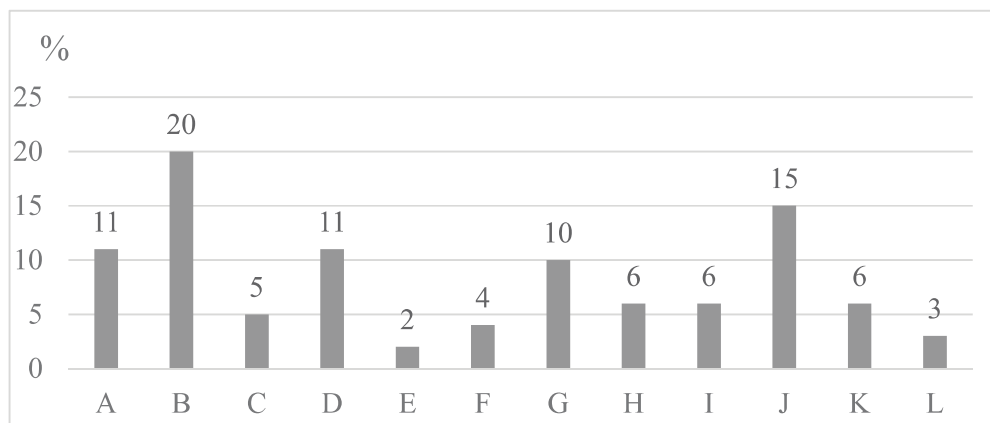

Figure 14. Methods of studies reviewed

Notes: Category: A - Archival; B - Case study; C - Comparative; D - Conceptual; E - Empirical; F - Experiment; G - Interview; H - Life cycle assessment (LCA); I - Observation ; J - Survey; K - Review; L - Non-applicable.

Source: The authors' calculation

The result shows that 37.5% of all papers, which is equivalent to 54 studies, utilized two or more methods in their analysis and research design. The research with one main methodology is almost twice as much, with 89 papers, taking up to 61.8% of all papers. Only one research did not apply any of method in the categories suggested in the coding scheme developed for this paper.
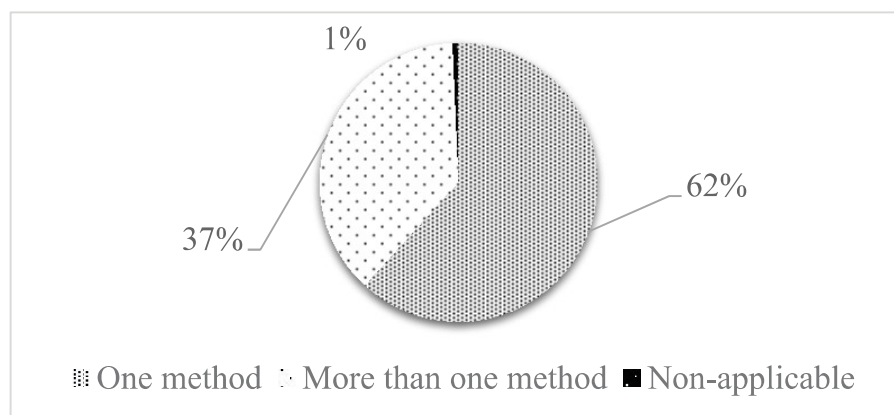

Figure 15. Combination of methods in studies reviewed

Source: The authors' calculation

Data source

A considerable proportion of articles combine more than one data source to perform their analysis. This type of research takes up 34% in the total reviewed studies. About 23% of total papers use data source as listed in Categories A and C. About 6% of total papers use data source as listed in Categories A and B. About 4% of total papers use data source as listed in Categories B and C. About 1% of total papers use all three methodologies specified in this classification.
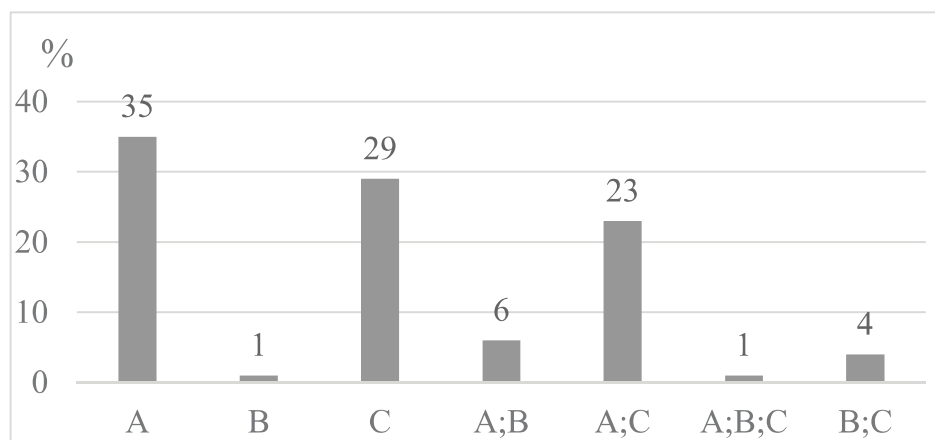

Figure 16. Data source of studies reviewed

Notes: Category: A - Primary data; B - Previous studies; C - Reports, publications, databases, and training materials.

Source: The authors' calculation

4.5 Results

As can be observed from the graph below, the distribution of different types of research results recorded is fairly balanced. Each category to a certain point acquires a good portion of studies, and the gaps observed among them are not too significant. Category C, representing the research results that tackle "Previous concepts/models/frameworks with new perspectives", had the highest portion (34%) with 49 articles. About 38 papers analyze "Previous perspectives with new dataset/time period" (Category D). About 31 articles present their results with "Proposal of new frameworks/concepts/strategies/ models" (Category B). The rest 15 papers are in Category A - "Consistent with the previous study". There are only 11 studies, which account for 7.6% of all papers, did not meet any applied code for this classification.
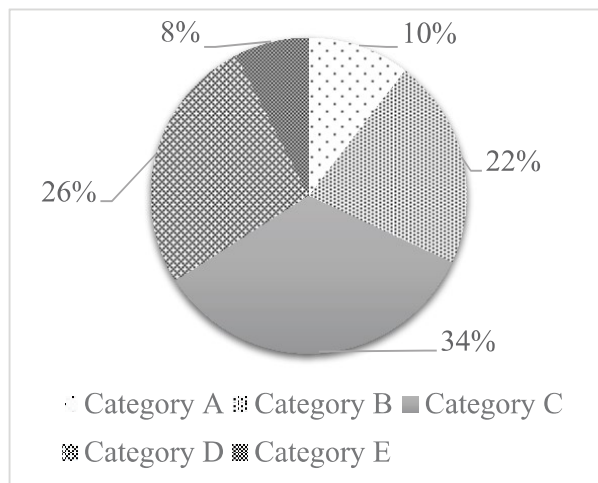

Figure 17. Results of studies reviewed

Notes: Category: A - Consistent with previous studies; B - Proposal of new frameworks/ concepts/ strategies/models; C - Previous concepts/models/frameworks with new perspectives; D - Previous perspectives with new dataset/time period; E - Non-applicable.

Source: The authors' calculation

The results reported for all classifications in this review involve intensive analysis of the coding outcomes encompassed by a consistent coding scheme and reference to theoretical definitions and principles of the subject provided in the previous chapters. All data were transparently recorded in tables then illustrated in graphs and charts for better visual observation, attributing to the exploration and further interpretations on linkages among fundamental factors of sustainable waste management in the present research.

5. Research trends and gaps

5.1 Research trends

Current trends in sustainable waste management research

There are several dispersive trends in the current literature on sustainable waste management. Each paper tends to focus its analysis on a small-scaled context, location, geographical region within a specific period of time.

Diversity is also actively exhibited when classifying and analyzing the research design of the reviewed papers. For every single research, distinctive data collection and analysis methods are applied, and moreover, combined in exclusive ways to approach the subject of study targeted adequately. Especially, due to typical features of sustainable waste management topic, the application of specific methods is frequently detected, for example, Life-cycle-assessment (LCA). According to Brusseau (2019), LCA serves as a comprehensive method in assessing the potential impacts of a product, process, procedure, activity or technology on the environment, from which scholars and decision-makers can come up with interpretations and resolutions to achieve the desired outcomes. Brusseau (2019), therefore, considers LCA as an exceptionally effective methodology in promoting sustainable development.

The progress of sustainable waste management studies during the studied period

The evolution of sustainable waste management studies in the time-period investigated in this review can be perceived from the evaluation of both quantity and quality. This progress in quantity is dramatic, yet comprehensible, considering that period from 2020 is declared by the world leaders at the sustainable development goals summit in September 2019 as the decade of action and transfer for sustainable development since it marks a milestone in the journey of approaching SDGs with only ten years left to achieve the desired outcomes for the whole globe (United Nations, 2020).

5.2 Research gaps

First, there exists a shortage of research on sustainable waste management in developed countries. The current focus of studies in this field should be placed more on developing countries due to the higher intensity of associated problems there. However, the distribution should not be over-biased towards developing countries and negligible to developed ones. Although developing countries are not often equipped with sufficient technology and facilities to achieve sustainable waste management, resulting in apparently severe situations caused by improper waste handling, the most considerable amount of waste generated globally comes from developed countries.

Second, an inadequacy for studies on Africa and Australia is detected. This gap in the long term can be detrimental since the ignorance of any geographical regions will result in the omittance of fundamental factors relating to the topic. In this case, the sparse population in Oceanian countries does not assure the insignificance of problems in waste management systems. Australia generated 67 million tonnes of waste from 2016 to 2017 (Yara Murray-Atfield, 2019), which is by no means a trivial amount. Also, although the current concern for African countries is mainly placed on primary issues such as poverty, diseases or water shortage, the importance of sustainable waste management cannot be underestimated.

The third gap lies in the limited amount of research on sustainable waste management in rural and suburban areas. As previously mentioned, the cities are receiving more attention on this topic due to the larger population and the availability of facilities. However, it is essential

to highlight the fact that rural and suburban regions also require an approximately similar focus.

Fourth, the extreme concentration of current sustainable waste management on solid waste creates a shortage of research on other types of waste. Particularly, hazardous waste, though accounting for a small portion of waste generated, holds potentially disastrous impacts on both the physical environment and biotic components (Syed, 2006). Considering the consequences of mishandling and benefits from efficiently disposing of such waste, the need for more attention paid towards them is no more questionable.

Fifth, studies on sustainable waste management in private, non-profit, and non-governmental sectors can hardly be considered adequate to support the implementation of new procedures and innovations in the field. This shortage for research in this category is a loss to the literature on sustainable waste management since the mentioned social sectors are considerably active in the promotion of sustainable development and several related spheres. The private sector can be a potential funding source for scholars in conducting their studies while non-governmental and non-profit organizations are the leading forces in advocating the enhancement of knowledge on sustainable waste management.

Finally, the most significant gap perceived in every analyzed category of existing sustainable waste management literature is the separation and scatter of research in this field. Observably throughout the present research, available publications are disassociated and sporadic, even though their main topics are all sustainable waste management. This gap is also reflected in the unavailability of an official and widely accepted framework for classifying types of waste among sustainable waste management. Besides, there is much research with proposals of various new frameworks, models, concepts, perspectives since sustainable waste management is still a relatively new subject; however, there is hardly any research that systemizes what is available and what is yet to be confirmed.

6. Conclusion and recommendations

Sustainable waste management has been growing as a topic of concern during the last ten years, provoking the drastic increase in the quantity and quality of research. This study has conducted a literature review of past and present research on sustainable waste management within the context of UN SDGs adoption in 2015. The study collects articles from top journals of seven worldwide prestigious publishers for scanning, screening, selecting, in-depth analysis, and critical evaluation. Reviewed papers are limited to publications in the ten years from 2010 to 2020, aiming to examine the effects of the UN SDGs on sustainable waste management, assessing the quality of recent research, and identifying the trends and gaps underlying in every paper.

Further research on sustainable waste management can be developed based on the two perspectives. The publication of more advanced studies to delimitate the existing limitations specified in this review is profoundly encouraged. Otherwise, researchers are recommended to spend more effort in conducting research reviews on frequently keeping track of the current

status of literature on the topic and providing more precise direction for the latter published studies.

Some limitations of this literature review can be noted. First, some relevant studies are inevitably missed out during the literature search. Particularly, included papers are limited to publications by famous publishers and, as a result, cannot be generalized to every other publisher in the world with a larger and more diverse sample. Besides, the review only takes into consideration articles in English, hence, probably omitted relevant articles in other languages. A few other unpublished yet well-qualified research also remain unexplored. Second, the method for data collection and analysis in this review is still basic and simple, with the ordinary searching tools available on selected publishers' websites. More sophisticated and advanced methods can be applied to provide more precise results in future research.

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