

Two decades of research on waste management in the circular economy: Insights from bibliometric, text mining, and content analyses

Original

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1 **Two decades of research on waste management in the circular economy:**
2 **insights from bibliometric, text mining, and content analyses**

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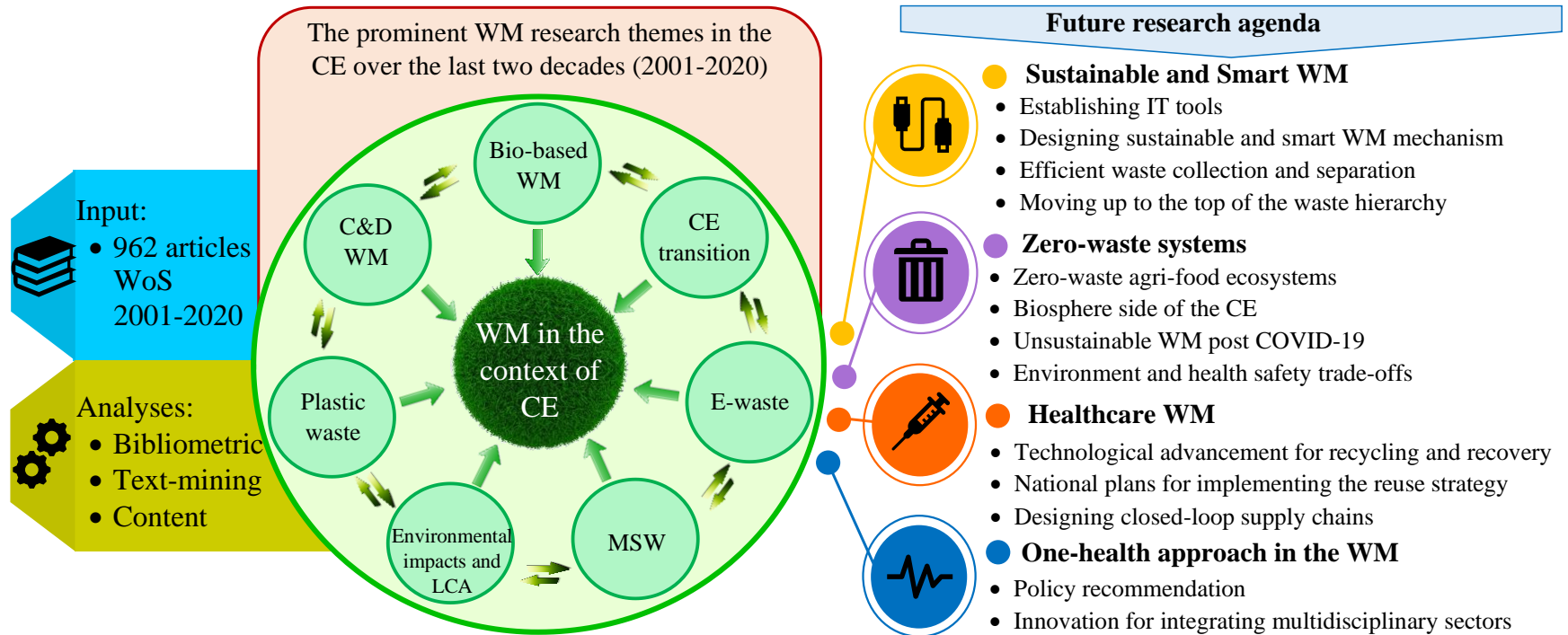
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34 **Graphical Abstract**

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38 **Abstract**

39 Achieving environmental sustainability and transition from a linear economy to a circular
40 economy (CE) highly relies on effective waste management (WM) and how waste is treated as a
41 potential future resource. This research aims to provide an inclusive map of the scientific
42 background of WM in the CE context over the last two decades from 2001 to 2020 to identify its
43 salient research themes and trends, main characteristics, evolution, and potentially valuable
44 directions for future studies. To achieve that, the following research questions were addressed by
45 applying a mixed-method approach including bibliometric, text mining, and content analyses: (i)
46 how has the field of WM research evolved within the CE domain? (ii) what are the salient research
47 themes and trends of WM in the CE? and (iii) what are the possible directions for future research
48 on WM within the CE context? As a result, the synthesized bibliometric networks were constructed
49 and analyzed for a total of 962 journal articles extracted from the Web of Science database to
50 visualize the main body of literature. Consequently, the seven major research themes of WM in
51 the CE context were identified as follows: (1) bio-based WM; (2) CE transition; (3) electronic
52 waste; (4) municipal solid waste; (5) environmental impacts and lifecycle assessment; (6) plastic
53 waste; and (7) construction and demolition WM. The provided inclusive research landscape of
54 WM systems, and its prominent highlight patterns can serve as a base for a real-time guideline to
55 lead further research areas and as a tool to support WM policy-makers and practitioners to support
56 the CE transition (which aims to minimize the waste generation). Finally, the future research
57 directions to better position WM research activities within the CE context as a waste minimization
58 approach are provided.

59
60 **Keywords:** waste management; circular economy; bibliometric analysis; text mining; content
61 analysis; environmental sustainability

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69 **Highlights**

- 70 • The literature on waste management (WM) in the circular economy (CE) was mapped.
71 • Bibliometric networks were constructed for a total of 962 journal articles.
72 • The seven major research themes of WM in the CE context were presented.
73 • Directions for future research on WM towards the CE transition were proposed.

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77 **Abbreviations**

CE	Circular Economy
WM	Waste Management
MSW	Municipal Solid Waste
C&D	Construction and Demolition
OFMSW	Organic Fraction of Municipal Solid Waste
WEEE	Waste Electrical and Electronic Equipment
E-waste	Electronic Waste
IT	Information Technology
IoT	Internet of Things
OH	One Health

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90 **1. Introduction**

91 Circular economy (CE), with a particular focus on the waste hierarchy from waste prevention
92 at the top to disposal at the bottom, intends to close the supply chain loops as much as possible
93 towards making a sustainable and zero-waste environment (Aghbashlo et al., 2018). The proper
94 management of waste plays a significant role in supporting environmental sustainability and
95 human health and transitioning from a linear economy to a CE (Aghbashlo et al., 2019b).
96 Designing and managing efficient waste management (WM) system as a foundation for the CE
97 establishment (Di Foggia and Beccarello, 2021) is crucial to achieving better resource management
98 and more waste prevention (Zeller et al., 2019).

99 In recent years, extensive research on WM practices corresponding to the CE goals has been
100 increasingly conducted. Those include but are not limited to developing CE indicators for WM
101 (Luttenberger, 2020), WM drivers towards a CE (Calderón Márquez and Rutkowski, 2020),
102 identifying barriers and challenges in the transition to a CE (Zhang et al., 2019), waste hierarchy
103 index for the CE (Pires and Martinho, 2019), and enablers of E-waste management in a CE
104 (Sharma et al., 2020). Bibliometric analysis has assisted researchers in dealing with numerous
105 publications in the WM research arena towards a CE. Accordingly, various research teams have
106 quantitatively analyzed and mapped the development of different lines of WM in the CE on a
107 broader outlook, such as municipal solid waste (MSW) management (Tsai et al., 2020), waste
108 incineration (Xing et al., 2019), and construction and demolition (C&D) waste (Wu et al., 2019).
109 However, WM activities compliant with the CE principles in practice are still blurred in the
110 existing studies (Tsai et al., 2020) and remain a challenge for WM policy-makers and CE
111 practitioners. Consequently, a holistic map of the WM research themes and trends aligned with
112 CE perspectives is lacking in the literature.

113 The present research aims to provide a body of knowledge for WM in the CE and its salient
114 research themes and trends, main characteristics, evolution, and directions for future studies by
115 scrutinizing the WM literature in the context of CE over the last two decades (2001–2020). The
116 provided analysis can serve as a base for a real-time manner guideline for future research in this
117 area. To achieve the aim of this study, a mixed-method approach, including bibliometric analysis,
118 text mining, and content analysis, is applied to answer the following research questions:

119 **RQ1.** How has the field of WM research evolved within the CE domain?

120 **RQ2.** What are the salient research themes and trends of WM in the CE?

121 **RQ3.** What are the possible directions for future research on WM towards the CE
122 transition?

123 To the best of our knowledge, there is no comprehensive research in the literature that
124 synthesized bibliometric, text mining, and content analyses concurrently in the field of WM within
125 the CE context. Therefore, our study is expected to immensely contribute to (i) capturing the
126 scientific background of WM research in the CE context and identifying its main themes and trends
127 over the last two decades, (ii) drawing an inclusive research landscape for the WM system and its
128 prominent highlight patterns, as a tool to support WM policy-makers and practitioners towards a
129 CE transition, and (iii) providing future research directions in WM that need more investigation to
130 establish a CE in practice.

131 The remainder of this paper is structured as follows. Section 2 provides an overview of the
132 WM practices towards a CE. Section 3 presents the adopted research methodology framework.
133 The obtained results from the bibliometric analysis, text mining, and content analysis on the WM
134 literature within the CE domain are discussed in section 4. Implications for research and avenues
135 for future studies are developed in section 5. Finally, section 6 delivers the conclusions and
136 research limitations for further development.

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138 **2. Waste management in a circular economy: an overview of opportunities and** 139 **challenges**

140 Waste management refers to all the activities and actions required to manage waste from its
141 inception to its final disposal through the collection, transport, and treatment phases (Rajaeifar et
142 al., 2017). The appropriate management, mitigation, and valorization of waste are essential for a
143 sound CE to transform our society towards a sustainable and zero-waste environment (Aghbashlo
144 et al., 2019a). A proper WM system enables collecting discarded, worn out, and/or obsolete
145 products to prevent them from being left out in nature and polluting the environment (Nelles et al.,
146 2016). However, such a WM system enables the suitable processing of waste to facilitate their
147 reinjection in CE loops, thus avoiding the extraction of primary materials (Romero-Hernández and
148 Romero, 2018). Several authors have indeed highlighted the importance of WM systems as a key
149 pillar in a CE to realize or make feasible most of the 10R-strategies namely, R0 Refuse/Rethink,

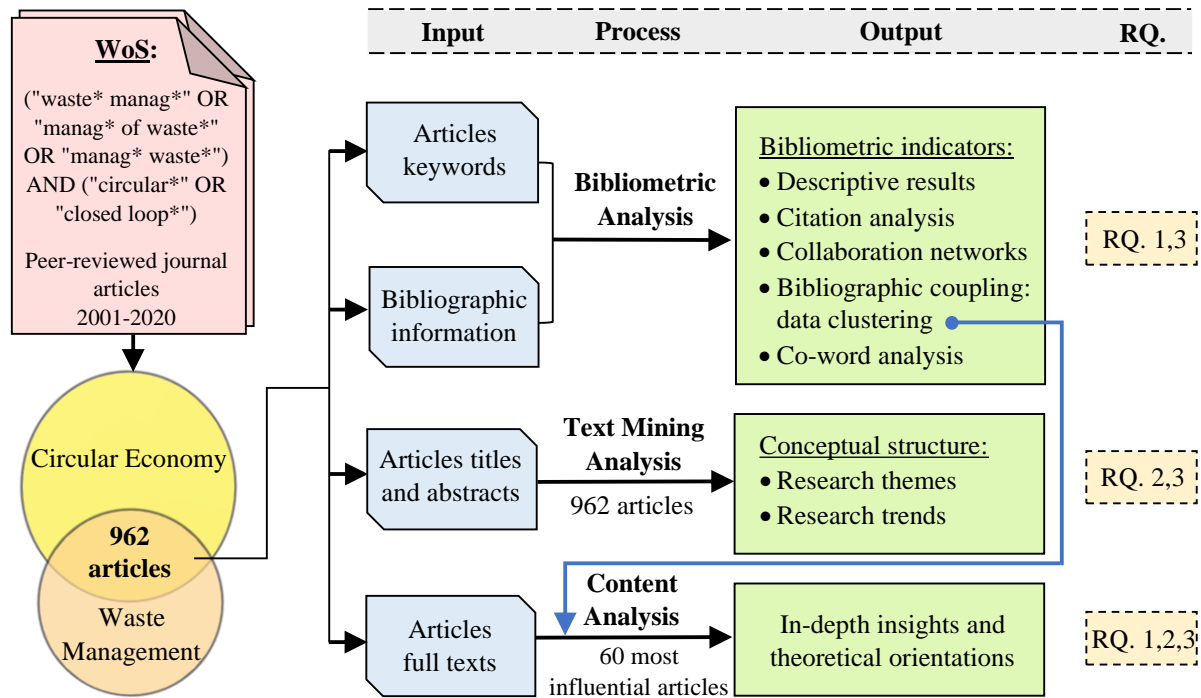
150 R1 Reduce, R2 Resell/reuse, R3 Repair, R4 Refurbish, R5 Remanufacture, R6 Repurpose, R7
151 Recycle, R8 Recover, and R9 Re-mine (Reike et al., 2018). Waste and pollution prevention are the
152 key reasons or objectives of developing a CE (Bilitewski, 2012). The notion of waste is central in
153 the numerous definitions of a CE: performing a text mining analysis on 70 definitions of a CE,
154 Saidani et al. (2020) found that waste is the sixth most-cited term in those definitions, after
155 economy, circular, resources, materials, and economic; and before, system, use, product, value,
156 production, and recycling.

157 While the current momentum around the CE concept could foster actions for better managing
158 waste globally, Zhang et al. (2019) remind that WM systems need to be smarter for a zero-waste
159 CE vision. Moreover, through a systematic review of zero-waste studies published between 1997
160 and 2014, Zaman (2015) found out that although policy-makers had embraced the zero-waste
161 concept, there was still a lack of advanced work or applied research in the domains of zero-waste
162 design, assessment, and evaluation. On this basis, it is of the utmost importance not only to
163 demonstrate that WM practices can be cost-saving and revenue-generating opportunities (Romero-
164 Hernández and Romero, 2018), but also can guide and monitor the activities of companies and
165 businesses towards more circular and zero-waste practices through appropriate circularity
166 indicators (Saidani et al., 2019). For instance, Di Maio and Rem (2015) proposed a "circular
167 economy index" as the ratio of the material value produced by the recycler (market value) by the
168 intrinsic material value entering the recycling facility. According to the authors, such an index
169 takes into account the strategic, economic, and environmental aspects of recycling and offers a
170 manageable amount of information to support decision-making tools. While other indicators or
171 metrics have been developed recently for a CE in WM, such as the "waste hierarchy index" (Pires
172 and Martinho, 2019), there is no widely acknowledged, commonly agreed (Zaman, 2015), or
173 standardized index for WM systems across countries or industrial sectors.

174

175 **3. Research methodology**

176 This research used a mixed-method approach that involved both quantitative and qualitative
177 analyses in scrutinizing the literature of WM in the CE, as presented in sections 3.1 and 3.2. The
178 overall research design is illustrated in Fig. 1.



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Fig. 1. Research framework design.

182 3.1. Data sampling, collection, and cleaning

183 To ensure sufficient coverage of related publications within the field of study, the Web of
 184 Science (WoS) Core Collection, as one of the most leading sources of scientific publications, was
 185 selected for collecting data in this research. The following search string was used to explore within
 186 the title, abstract and keywords fields: ("waste* manag*" OR "manag* of waste*" OR "manag*
 187 waste*") AND ("circular*" OR "closed loop*"). The initial search was conducted in January 2021
 188 and was limited to peer-reviewed journal articles and reviews in the English language and the
 189 period of 2001–2020. After removing missing values, a total of 962 articles met the selection
 190 criteria and were used as the final sample for the analysis. As a fundamental preparation step for
 191 the keyword-based analyses, the final dataset was cleaned before conducting the bibliometric and
 192 text mining analyses (Ranjbari et al., 2020). In this vein, synonyms such as environmental effect
 193 and environmental impact, or E-waste and electronic waste, were merged. Besides, the unification
 194 of writing styles and merging singular and plural forms of the keywords was done, and keywords
 195 without any explicit meaning for this study's focus, such as "literature review" and "article," were
 196 removed from the dataset to increase the analyses' reliability.

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3.2. Data analysis

Three analytical methods, including bibliometric, text mining, and content analyses, were employed in this research to examine the evolution and structure of the research field.

3.2.1. Bibliometric analysis

Bibliometric analysis, a quantitative technique and powerful statistical tool to deal with a large number of publications and scientific literature mapping, has been increasingly used during recent years in various fields of research, such as CE (Goyal et al., 2020), sustainable development (Du et al., 2021), and open innovation (Gao et al., 2020). The bibliometric analysis supports researchers in quickly identifying future research directions within a field of study by providing an inclusive visualization of relationships among articles, journals, keywords, citations, and co-citations networks (Feng et al., 2017). VOSviewer version 1.6.16 was used to conduct the bibliometric analysis (van Eck and Waltman, 2010). Different bibliometric parameters, including publications evolution over time, citation analysis for core publications and authors, collaboration analysis for countries and institutions, bibliographic coupling network analysis for data clustering, and finally, co-word analysis for identifying hotspots were presented in this research to statistically map the bibliometric information of scientific publications in WM within the CE context over the last two decades.

3.2.2. Text mining analysis

Text mining technique, a tool for extracting information from an extensive collection of documents in text form and analyzing research themes and trends (Jung and Lee, 2020), has been widely employed by researchers in various fields of CE studies. Text mining analysis can particularly capture semantic structures and phrase patterns that best characterize a vast amount of text data. A text mining analysis based on a term co-occurrence algorithm was employed in this research on the concatenation of the titles and abstracts of the publications within the dataset using VOSviewer version 1.6.16. As a result, the conceptual structure and latent research themes and trends of the WM literature in the CE domain were identified.

226 3.2.3. Content analysis

227 In line with the research conducted by Schöggl et al. (2020) and Jia and Jiang (2018), a content
228 analysis, as a complementary qualitative layer, was also carried out in this research to improve the
229 confidentiality of the results and to provide more in-depth insights for the quantitative findings of
230 the investigation. In this sense, a qualitative content analysis using the data clustering technique
231 was conducted for the top 15 most influential articles within each cluster obtained from the
232 bibliographic coupling analysis to investigate the theoretical orientations in the WM towards the
233 CE.

234

235 4. Results and Discussion

236 To clearly address our study's research questions, the results are presented in sections 4.1, 4.2,
237 and 4.3, corresponding to the respective research questions.

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239 4.1. Bibliometric mapping of extant studies

240 The bibliometric analysis indicators are presented in this section to directly address the first
241 research question:

242 **RQ1.** How has the field of WM research evolved within the CE domain?

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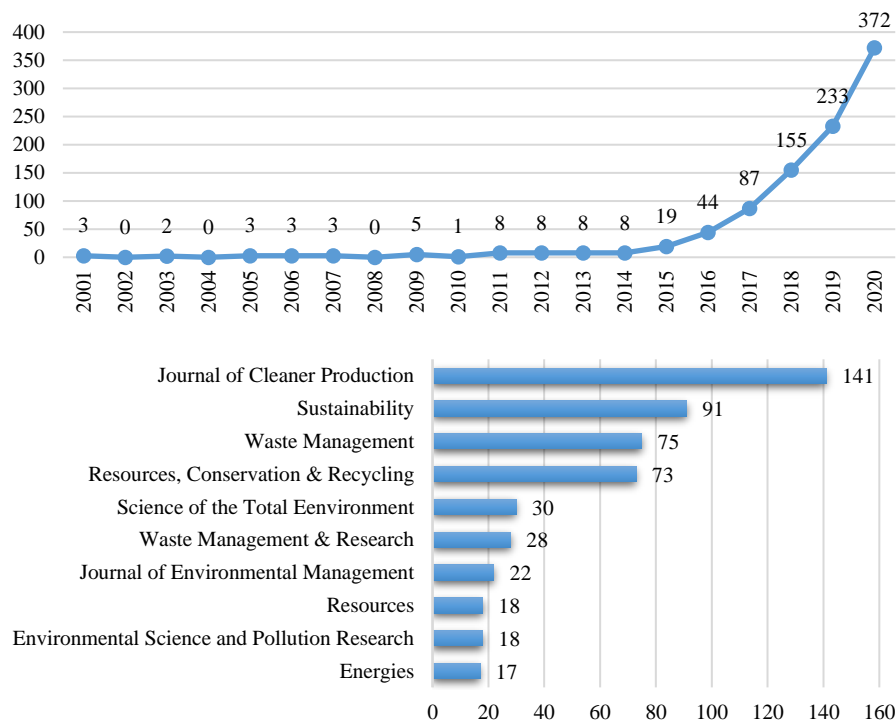
244 4.1.1. Descriptive analysis: publications evolution

245 Fig. 2 illustrates the publication trend of WM-related research in the CE from 2001 to 2020.
246 The majority of articles (i.e., 910 out of 962) were published after 2014, accounting for over 94%
247 of the data sample. It could be concluded that the primary research period in terms of the number
248 of publications and academic involvement in WM towards a CE would be 2015 to 2020. Consistent
249 with Reike et al. (2018), this significantly increasing number of scholarly publications in the last
250 five years denotes that the CE establishment has received growing attention within different
251 domains, such as WM.

252 A total of 254 journals have published 962 articles on WM considering CE from 2001 to 2020.
253 The top 10 journals contain 513 out of 962 items, representing 53% of the publications in the field
254 of WM corresponding to the CE perspectives, and are shown in Fig. 2. In this regard, *Journal of*
255 *Cleaner Production* played the most dominant role in this field, with 141 out of 962 articles,

256 constituting approximately 15% of the publications, and was followed by *Sustainability*, *Waste*
 257 *Management*, and *Resources, Conservation & Recycling* with 91, 75, and 73 articles, respectively.

258



259 **Fig. 2.** Publications evolution in terms of number and leading journals over time from 2001–
 260 2020.

261 **4.1.2. Citation analysis: core articles and authors**

262 The number of citations received by an article can be considered as a suitable measure for
 263 identifying the most influential publications in a research domain (Merigó et al., 2015). The top
 264 10 highly cited articles within our dataset are shown in Table 1. Six out of 10 highly cited articles
 265 have been published in *Journal of Cleaner Production*, which denotes this journal's significant
 266 contribution to the transition from a linear economy to a CE. The most cited paper is a
 267 comprehensive review of the CE implementation conducted by Ghisellini et al. (2016), which has
 268 been cited 998 times until January 22, 2021, based on the WoS database. The next highly cited
 269 research works have been carried out by Lieder and Rashid (2016), reviewing CE implementation
 270 in the manufacturing industry and Su et al. (2013), assessing the CE development in China,
 271 respectively. As it can be clearly seen from Table 1, the most cited papers in this research area are
 272 review articles focusing on the CE perspectives and implementation. This may have occurred due

273 to two reasons. First, the CE transition, on account of its potential advantages for economic and
 274 environmental regimes, has been the focal point of attention for researchers over the last few years.
 275 And second, implementing CE in practice is still challenging for policy-makers and lacks a clear
 276 guideline for practitioners involved in operation levels.

277

278 **Table 1.** The top 10 highly cited articles in the WM research towards the CE.

Rank	Article title	TC*	TC/Y**	Author(s)	Journal
1	A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems	998	166.33	(Ghisellini et al., 2016)	J Clean Prod
2	Towards circular economy implementation: a comprehensive review in the context of manufacturing industry	501	83.50	(Lieder and Rashid, 2016)	J Clean Prod
3	A review of the circular economy in China: moving from rhetoric to implementation	374	41.56	(Su et al., 2013)	J Clean Prod
4	Concurrent product and closed-loop supply chain design with an application to refrigerators	230	12.11	(Krikke et al., 2003)	Int J Prod Res
5	A review of reverse logistics and closed-loop supply chains: a Journal of Cleaner Production focus	204	40.80	(Govindan and Soleimani, 2017)	J Clean Prod
6	Sewage sludge disposal strategies for sustainable development	198	39.60	(Kacprzak et al., 2017)	Environ Res
7	Strategies on implementation of the waste-to-energy supply chain for the circular economy system: a review	187	26.71	(Pan et al., 2015)	J Clean Prod
8	The history and current applications of the circular economy concept	186	37.20	(Winans et al., 2017)	Renew Sust Energy Rev
9	Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe	178	35.60	(Malinauskaite et al., 2017)	Energy
10	How do scholars approach the circular economy? A systematic literature review	161	40.25	(Merli et al., 2018)	J Clean Prod

279 * Total citation; ** Total citation per year

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282 The productivity (i.e., the number of publications) and influence (the number of received
 283 citations) of the top authors contributing to the WM research towards the CE are presented in Table
 284 2. Ulgiati, Chisellini, and Cialani are the most influential authors with 1131, 1094, and 998 total
 285 citations, respectively. On the other hand, Smol with 12 articles, Torretta with 11 articles, and
 286 Ferronato with 9 articles are the most productive authors within the study period. Geng with 8
 287 articles and 713 total citations, has appeared in both lists of the top 10 influential and productive
 288 authors, making this researcher a leading author within the CE domain.

289

290 **Table 2.** The most influential and productive authors in the WM research towards the CE.

Most influential authors				Most productive authors			
Rank	Author	TC*	TP**	Rank	Author	TP	TC
1	Ulgiati, Sergio	1131	4	1	Smol, Marzena	12	268
2	Ghisellini, Patrizia	1094	3	2	Torretta, Vincenzo	11	158
3	Cialani, Catia	998	1	3	Ferronato, Navarro	9	158
4	Geng, Yong	713	8	4	Geng, Yong	8	713
5	Lieder, Michael	500	1	5	Irabien, Angel	8	101
6	Rashid, Amir	500	1	6	Purnell, Phil	7	137
7	Heshmati, Almas	373	1	7	Bialowiec, Andrzej	6	24
8	Su, Biwei	373	1	8	Koziel, Jacek A.	6	24
9	Yu, Xiaoman	373	1	9	Zabaniotou, A.	6	109
10	Smol, Marzena	268	12	10	Zorpas, Antonis A.	6	65

* Total citation; **Total publication

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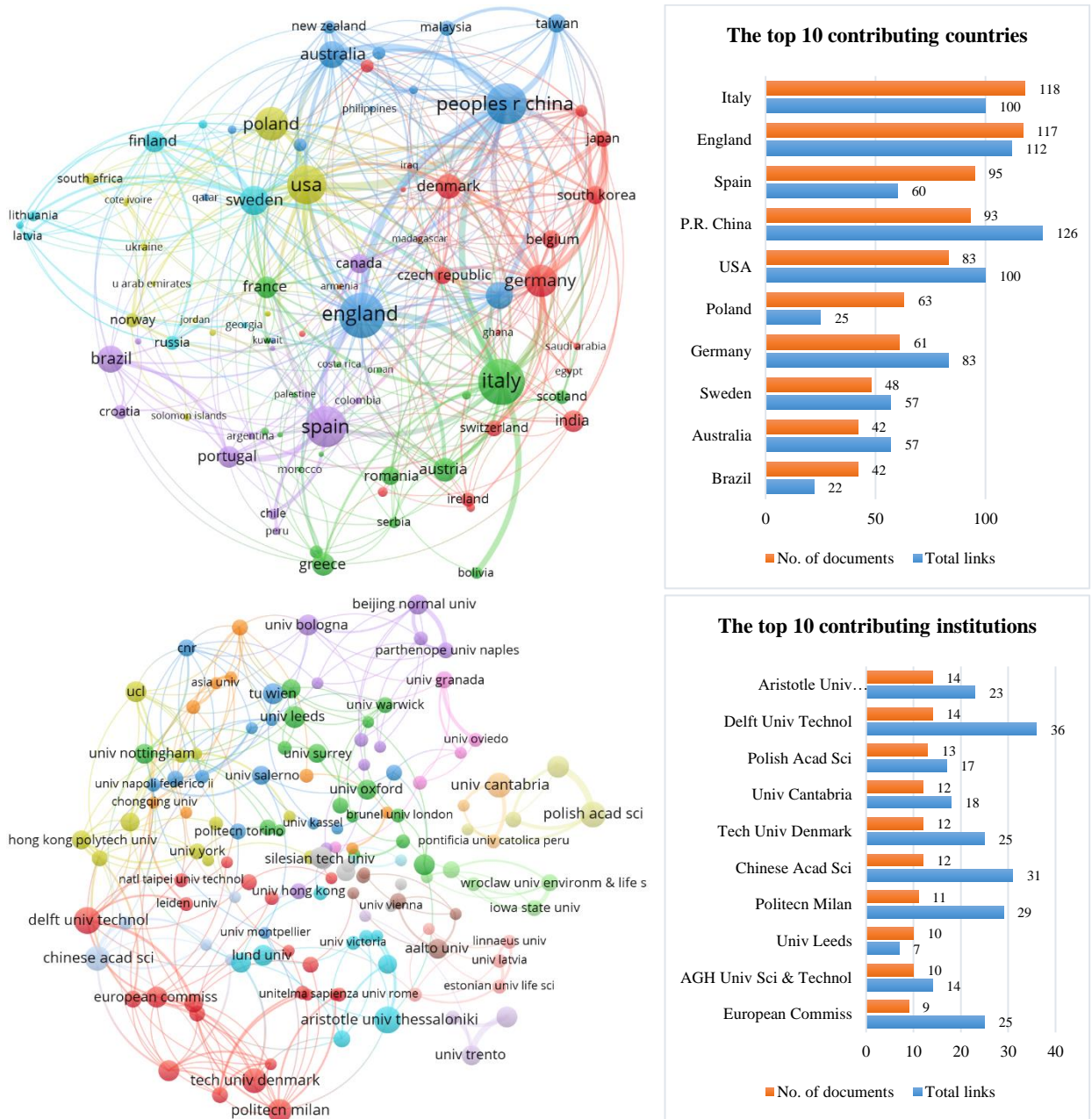
293 4.1.3. Collaboration analysis: institutions and countries

294 Out of 88 countries and 1248 institutions contributing to our sample, the most contributing
295 countries and institutions on the subject are illustrated in

296 Fig. 3. In this figure, the larger each circle is, the higher the number of documents the
297 corresponding country and institution have. Moreover, the thicker the link between the circles, the
298 more collaboration has occurred between them. Based on the results, Italy, England, Spain, China,
299 and the USA are the pioneers in the WM research in the context of CE with 118, 117, 95, 93, and
300 83 articles, respectively. In terms of collaboration, China, with 126 international collaborations, is
301 the leading country within the global network on the subject. England with 112, and Italy and the
302 USA, both with 100 collaboration links, come next in this network. On the contrary, Poland with
303 25 and Brazil with 22 collaborations have the least developed network among the top 10
304 contributing countries.

305 Due to the large number of institutions involved in this study (n= 1248), only the institutions
306 with at least three articles have been plotted in Figure 3 to better visualize the highly contributing
307 institutions. Surprisingly, although The Netherlands and Greece are not among the top 10
308 contributing countries on the subject, the Delft University of Technology from The Netherlands
309 and Aristotle University of Thessaloniki from Greece are equally the most active institutions with
310 14 contributions. Polish Academy of Sciences from Poland with 13, University of Cantabria from
311 Italy, the Technical University of Denmark from Denmark, and Chinese Academy of Sciences
312 from China all together with 12 articles are the next most contributing institutions. Besides, the
313 Delft University of Technology, Chinese Academy of Sciences, and Polytechnic of Milan with 36,

314 31, and 29 collaboration links are the most actively collaborating institutions among all institutions
 315 in this study.



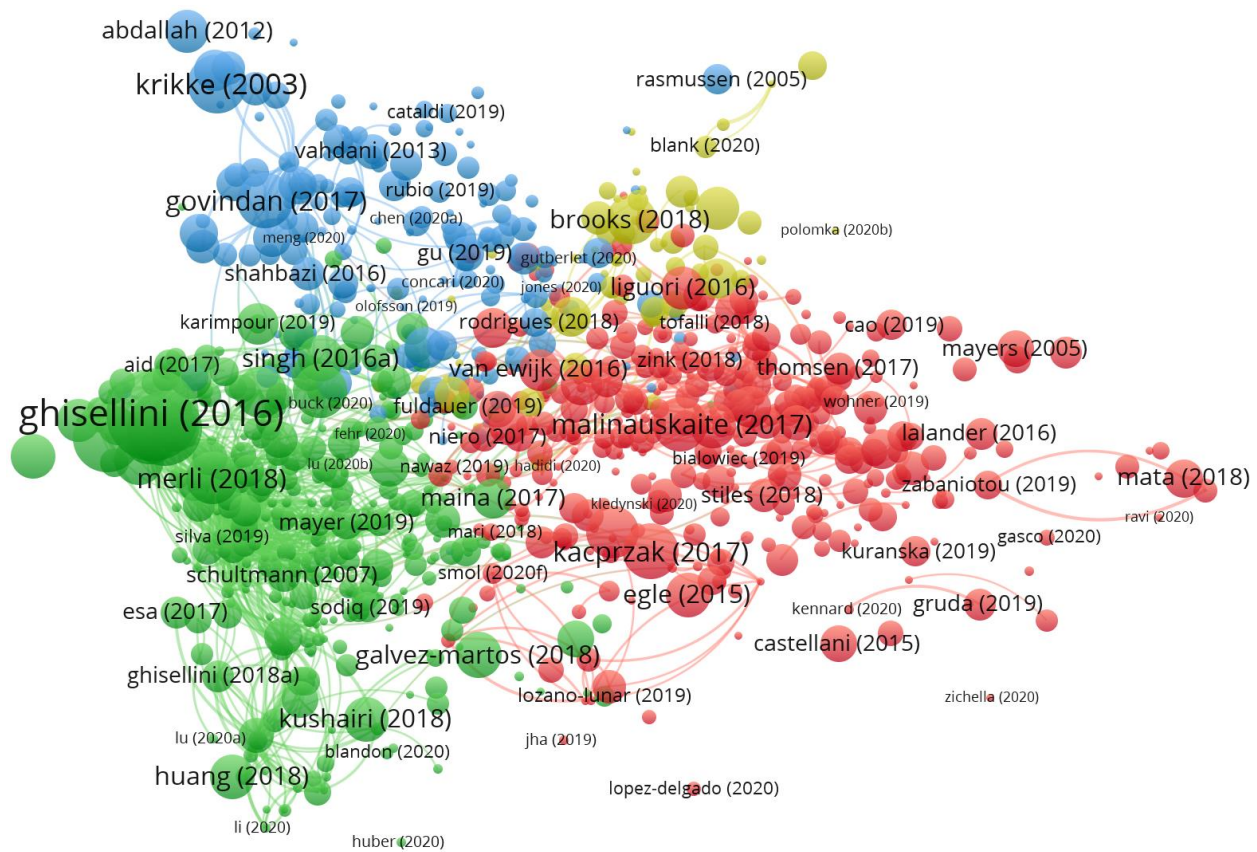
316
 317 **Fig. 3.** Collaboration network between countries and institutions in the WM research towards the
 318 CE.

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320 **4.1.4. Bibliographic coupling network analysis: data clustering**

321 Data clustering technique to group the articles with analogous characteristics from a sample
322 for identifying the research orientations (Du et al., 2021) is a typical application of bibliometric
323 analyses. Bibliographic coupling analysis using VOSviewer was applied to perform data clustering
324 in our research. Bibliographic coupling links between publications indicate the number of cited
325 references they have in common (van Eck and Waltman, 2020). A total number of 926 out of 962
326 articles in our sample was used to construct the bibliographic coupling network, as shown in Fig.
327 **4**. According to the results, four clusters of articles were generated, which are shown in different
328 colors in Fig. **4**.

329



330

331 **Fig. 4.** Bibliographic coupling network of WM research towards the CE.

332

333 The four main clusters of articles are CE perspectives on waste hierarchy (cluster 1), CE
334 conceptualization and implementation (cluster 2), WM within closed-loop supply chains (cluster
335 3), and CE approach to plastic WM (cluster 4). The top 15 most influential articles of each cluster

336 are listed in Table 3. The obtained bibliographic coupling clusters and their influential articles will
 337 be addressed in detail in section 4.3 to conduct the qualitative content analysis and uncover the
 338 major themes and research orientations.

339

340 **Table 3.** The top 15 most influential articles within main clusters of WM research towards the
 341 CE.

Cluster 1: CE perspectives on the waste hierarchy	Cluster 2: CE conceptualization and implementation	Cluster 3: WM within closed-loop supply chains	Cluster 4: CE approach to Plastic WM
Kacprzak et al. (2017)	Ghisellini et al. (2016)	Krikke et al. (2003)	Brooks et al. (2018)
Malinauskaite et al. (2017)	Lieder and Rashid (2016)	Govindan and Soleimani (2017)	Sakai et al. (2011)
Smol et al. (2015)	Su et al. (2013)	Abdallah et al. (2012)	Koop and van Leeuwen (2017)
Sandin and Peters (2018)	Pan et al. (2015)	Lee and Chan (2009)	Horodytska et al. (2018)
Egle et al. (2015)	Winans et al. (2017)	Ferronato and Torretta (2019)	Van Eygen et al. (2018)
Liguori and Faraco (2016)	Merli et al. (2018)	Islam and Huda (2018)	Jambeck et al. (2018)
Van Ewijk and Stegemann (2016)	Reike et al. (2018)	Nikolopoulou and Ierapetritou (2012)	Payne et al. (2019)
Haupt et al. (2017)	McDowall et al. (2017)	Lu et al. (2015)	Pomberger et al. (2017)
Iacovidou et al. (2017b)	Gálvez-Martos et al. (2018)	Ferronato et al. (2019)	Eriksen et al. (2019)
Iacovidou et al. (2017a)	Singh and Ordoñez (2016)	Krikke et al. (2013)	Prieto (2016)
Blengini et al. (2012)	de Jesus and Mendonça (2018)	Vahdani et al. (2013)	Eriksen et al. (2018)
Agudelo-Vera et al. (2011)	Huang et al. (2018)	Gu et al. (2019)	Iacovidou et al. (2019)
Mata et al. (2018)	Bachmann (2007)	Özceylan et al. (2017)	Faraca and Astrup (2019)
Mayers et al. (2005)	Kushairi et al. (2018)	Pedram et al. (2017)	Foschi and Bonoli (2019)
Nižetić et al. (2019)	Dong et al. (2013)	Shahbazi et al. (2016)	RameshKumar et al. (2020)

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343 4.1.5. Co-word analysis: identifying hotspots

344 Authors' keywords in the articles can represent the main idea and border of their research. The
 345 co-word analysis based on the co-occurrence of words can support identifying research hotspots
 346 in a particular field of study (Gao et al., 2020). Before conducting the co-occurrence analysis, the
 347 keywords list was cleaned reasonably. In the end, 2641 out of 2889 keywords remained for the
 348 analysis. Excluding the keywords with the co-occurrence frequency below seven (for clearer
 349 visualization), the co-occurrence network of the authors' keywords containing 68 hot keywords is
 350 mapped in Fig. 5. In this map, the bigger the circles are, the more occurrence the keywords have,
 351 and the thicker the links between every two keywords is, the more co-occurrence they have.
 352 Besides, the circles' color corresponds to the average publication year of the articles in which a
 353 keyword occurs. Moving from dark blue to yellow shows that the documents containing the
 354 relevant keywords are more recent on average.

355 The ten most frequent keywords in our dataset are *circular economy*, *waste management*,
 356 *recycling*, *sustainability*, *lifecycle assessment*, *municipal solid waste*, *waste*, *food waste*, *industrial*
 357 *ecology*, and *material flow analysis*. These ten keywords also have the most connection links with
 358 the other keywords in the dataset. As shown in Fig. 5, keywords such as *waste hierarchy*, *lifecycle*,
 359 *closed-loop supply chain*, and *resource efficiency* are older in terms of the average publication

Table 4. Salient research themes in WM towards the CE.

No. and Label of the research theme	Main terms	Exemplary recent references
1. Bio-based waste management	Biochar, Bioeconomy, Bioenergy, Biofuel, Biogas production, Biomass, Biorefinery, Byproduct, Circular bioeconomy, Composting, Food waste, Food waste management, Organic Fraction of Municipal Solid Waste (OFMSW), Organic waste, Waste valorization	Imbert (2017), Ng et al. (2020), Tsai (2020), Zabaniotou and Kamaterou (2019), Loizia et al. (2019), Pérez-Camacho and Curry (2018), Cecchi and Cavinato (2019), Rekleitis et al. (2020), Kakadellis and Harris (2020), Elkhalfifa et al. (2019)
2. Circular economy transition	Circular economy, Resource, Sustainability, Sustainable development, Circularity, Supply chain, Business model, Resource recovery, Circular economy model, Circular economy practice, Circular economy strategy, Sustainable Development Goals, Industrial symbiosis, Recycle, Waste reduction	Shpak et al. (2020), Lu et al. (2020), Alvarez and Ruiz-Puente (2017), Okafor et al. (2020), Johansson and Henriksson (2020), Priyadarshini and Abhilash (2020)
3. E-waste	Behavior, Society, Government, E-waste, Consumer, Waste Electrical and Electronic Equipment (WEEE), Producer, Incentive, Manufacturer, Policymaker, Responsibility, Environmental protection, Waste disposal, Extended Producer Responsibility, WEEE directive	Sharma et al. (2020), Lu et al. (2015), Chen et al. (2020), Marke et al. (2020), Ottoni et al. (2020), Cole et al. (2019), Mayers et al. (2005)
4. Municipal solid waste (MSW)	Policy, MSW, Waste generation, Municipality, European Union, Recycling rate, Waste hierarchy, Waste collection, Household waste, Biowaste, Circular economy package, Packaging waste, Waste-to-energy, Secondary raw material, Separate collection	Malinauskaite et al. (2017), Kaza et al. (2018), Hadidi et al. (2020), Petryk et al. (2019), Smol et al. (2020), Abis et al. (2020), Morlok et al. (2017), Agovino et al. (2019), Valenzuela-Levi (2019), Siddiqi et al. (2020), Hadzic et al. (2018)
5. Environmental impacts and lifecycle assessment	Environmental impact, Landfill, Disposal, Emission, Incineration, Lifecycle assessment, Energy recovery, Climate change, Greenhouse gas emission, Environmental performance, Decision making, Recycling process, Material recovery, Environmental burden, Global Warming Potential	Thomsen et al. (2018), Jensen (2019), Peceño et al. (2020), Arushanyan et al. (2017), Boldoczki et al. (2020), Sandin and Peters (2018), Sauve and Van Acker (2020), Cortés et al. (2020), Zeller et al. (2020), Kouloumpis et al. (2020), Slorach et al. (2019), Gallego-Schmid et al. (2018)
6. Plastic waste	Recycling, Recovery, Plastic waste, Packaging, Chemical, Value chain, Human health, Threat, Prevention, Polymer, Rubber, End-of-Life, Recyclability, Contaminant, Single-use plastic	Sherwood (2020), Foschi and Bonoli (2019), Paziienza and De Lucia (2020), Andreasi Bassi et al. (2020), Leissner and Ryan-Fogarty (2019), Milios et al. (2018), Faraca and Astrup (2019), Eriksen et al. (2018), Eriksen et al. (2019)

7. Construction and Demolition (C&D) waste management	Technology, Raw material, Construction, C&D waste, Building, Concrete, Construction industry, C&D waste management, Sewage sludge ash, Industrial waste, Material efficiency, Slag, Steel, Energy consumption, Demolition	Kabirifar et al. (2020), Lederer et al. (2020), Jin et al. (2019), Esa et al. (2017), Li et al. (2020), Mahpour (2018), Smol et al. (2015), Mak et al. (2019)
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378 Bio-based WM has appeared as one of the leading research themes of WM in the CE context.
 379 In this regard, food WM poses a significant challenge on the transition from a linear economy to
 380 a CE (Imbert, 2017). The studies related to this research theme mainly focus on valorization and
 381 turning food waste into value-added resources and bioproducts (Imbert, 2017; Ng et al., 2020;
 382 Tsai, 2020; Zabaniotou and Kamaterou, 2019), optimization of energy production through
 383 anaerobic digestion in food WM (Loizia et al., 2019), using the anaerobic biorefinery to contribute
 384 to a regional bioeconomy (Pérez-Camacho and Curry, 2018), smart approaches to food waste final
 385 disposal (Cecchi and Cavinato, 2019), waste biomass from the agricultural-livestock sector
 386 (Rekleitis et al., 2020), lifecycle assessment of bioplastic-based food packaging (Kakadellis and
 387 Harris, 2020), and food waste to biochars through pyrolysis (Elkhalifa et al., 2019).

388 The second theme pertains to how a linear economy can be transitioned to a CE with a
 389 particular focus on WM practices and activities. Due to the lack of a precise mechanism for
 390 collecting, sorting, and distributing waste, the transition to a CE will be long and complicated
 391 (Shpak et al., 2020). For instance, developing measurement and index systems (Lu et al., 2020),
 392 creating synergies and industrial symbiosis among industrial sectors based on the substitution of
 393 raw materials from waste, sub-products or recycled materials (Álvarez and Ruiz-Puente, 2017),
 394 end-of-life mismanagement and its profound negative ecological implications (Okafor et al.,
 395 2020), discursive framing of CE policies (Johansson and Henriksson, 2020), and energy recovery
 396 from waste (Priyadarshini and Abhilash, 2020) have been highlighted in the literature, as some of
 397 the main WM challenges towards implementing a CE.

398 The significant increasing demand for using electrical and electronic products across the globe
 399 has made proper E-waste management a top priority for developed and developing countries,
 400 particularly those in the CE transition phase (Sharma et al., 2020). E-waste is one of the most
 401 challenging subjects for policy-makers in WM since inappropriate E-waste treatment and recycling
 402 can hugely affect the environment and human health (Lu et al., 2015). Studies categorized in the
 403 E-waste research theme mostly investigate critical barriers and pathways to the implementation of
 404 E-waste formalization management systems (Chen et al., 2020), application of the innovative

405 circular business models to support E-waste reduction (Marke et al., 2020), E-waste valorization
406 through developing adequate indicators for E-waste reverse logistics (Ottoni et al., 2020), solutions
407 and incentives to move up on the top of the waste hierarchy in the E-waste treatment, rather than
408 recycling (Cole et al., 2019), and the importance of modifying the E-waste directives and policy
409 guidelines to ensure addressing all lifecycle impacts (Mayers et al., 2005).

410 Due to the growing population of the world and rising living standards, the consumption of
411 goods, and consequently, waste generation levels have been considerably increasing over the
412 recent years (Malinauskaite et al., 2017). For instance, an estimated 2.01×10^9 t of MSW were
413 generated in the world in 2016, and it is expected to grow to 3.40×10^9 t by 2050 (Kaza et al.,
414 2018), which sounds alarming as a universal issue. The main research articles in the MSW theme
415 mainly concentrate on 3Rs (reduce, reuse, recycle) practices implementation to influence the
416 behavior of citizens (Hadidi et al., 2020), proposing incentives for public engagement in the MSW
417 management (Petryk et al., 2019), providing practical solutions for transformation towards CE
418 (Smol et al., 2020), increasing the collection rates of recyclables (Morlok et al., 2017), assessing
419 the synergy between recycling and thermal treatments (Abis et al., 2020), factors influencing
420 different collection rates and municipal recycling (Agovino et al., 2019; Valenzuela-Levi, 2019),
421 waste-to-energy systems using MSW to produce energy (Siddiqi et al., 2020), and lifecycle
422 assessment of solid waste management (Hadzic et al., 2018).

423 Through employing efficient WM systems, the CE aims to increase resource efficiency and
424 mitigate the environmental impacts of waste generation. Assessing the environmental implications
425 of WM practices has always been challenging to provide decision support for policy-makers to
426 make the optimal decisions regarding commitment to a clean and sustainable environment
427 (Khoshnevisan et al., 2020). According to the text mining analysis results in our study, the major
428 challenges of environmental evaluation within WM activities have been highlighted in the
429 environmental impacts and lifecycle assessment theme. For example, environmental analysis of
430 integrated organic waste and wastewater management systems (Thomsen et al., 2018),
431 environmental assessment of different recycling processes (Jensen, 2019; Peceño et al., 2020),
432 developing lifecycle assessment models for environmental assessment of possible future WM
433 scenarios (Arushanyan et al., 2017), measuring potential environmental benefits of preparation for
434 reuse before recycling (Boldoczki et al., 2020), environmental impacts of textile reuse and
435 recycling (Sandin and Peters, 2018), environmental impacts of MSW landfills (Sauve and Van

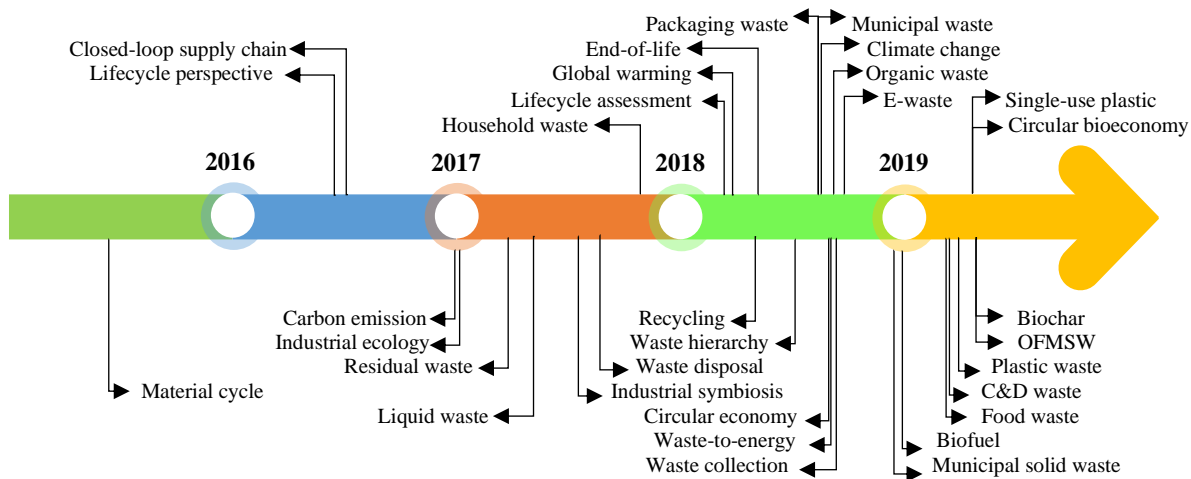
436 Acker, 2020), environmental burdens of composting as a way to achieve a more circular waste
437 valorization (Cortés et al., 2020), environmental consequences of CE options for biowaste flows
438 (Zeller et al., 2020), plastic waste effects on climate change (Kouloumpis et al., 2020),
439 environmental implications of recovering resources from food waste in a CE (Slorach et al., 2019),
440 and environmental impacts of the entire lifecycle of electrical and electronic waste (Gallego-
441 Schmid et al., 2018), are some of the most critical environmental studies in this research theme.

442 Due to its extensive applications in the industry and urban life, plastic has made WM face
443 various challenges and environmental concerns, from marine pollution to limited recycling. The
444 main addressed subject areas of the plastic waste theme in our study refer to closed-loop recycling
445 of polymers (Sherwood, 2020), the interaction between plastic value chain stakeholders, and
446 regulations towards implementing a CE (Foschi and Bonoli, 2019), defining a new plastics
447 economy in the agriculture sector (Pazienza and De Lucia, 2020), extended producer responsibility
448 for plastic packaging waste (Andreasi Bassi et al., 2020), challenges and opportunities for
449 reduction of single-use plastics (Leissner and Ryan-Fogarty, 2019), identifying critical barriers for
450 plastic recycling across the regional plastics value chain (Milios et al., 2018), evaluation of plastic
451 recyclability (Faraca and Astrup, 2019), contamination in plastic recycling and the quality of
452 reprocessed plastics (Eriksen et al., 2018), and circularity-potential assessment of recovery
453 systems for household plastic waste (Eriksen et al., 2019).

454 Finally, C&D waste generated throughout the construction cycle has been identified through
455 the text mining analysis as the last research theme of WM in the CE in our study. The rapid
456 urbanization in the world has increased the C&D waste (Kabirifar et al., 2020), which is considered
457 one of the largest waste streams (Lederer et al., 2020). Sustainable treatment of C&D wastes should
458 be employed globally as an urgent social, environmental, and economic issue (Jin et al., 2019). In
459 this regard, the scholars have paid close attention to developing strategies for managing C&D
460 wastes based on CE principles (Esa et al., 2017), application of information technologies in C&D
461 WM (Li et al., 2020), prioritizing barriers to adopt CE in C&D WM (Mahpour, 2018), using
462 sewage sludge ash in the construction industry as a way towards a CE (Smol et al., 2015), and
463 behavior and attitudes towards recycling of C&D waste in the community (Mak et al., 2019).

464 The revealed research themes of WM practices towards a CE obtained from the text mining
465 analysis on the abstracts of articles within our dataset allow mapping how WM subject areas have
466 evolved over the years based on their average publication year. Fig. 6 illustrates the timeline of

467 dominant research themes and their WM subject areas in the CE context over the recent five years.
 468 As shown in Fig. 6, biochar, Organic Fraction of Municipal Solid Waste (OFMSW), plastic waste,
 469 C&D waste, food waste, biofuels, circular bioeconomy, and single-use plastics have been
 470 attracting attention very recently, rather than material cycles, closed-loop supply chain, carbon
 471 emission, industrial ecology, and liquid waste.
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 475 **Fig. 6.** Timeline of dominant research themes and their WM subject areas in the CE context.
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477 **4.3. Qualitative content analysis of the four clusters: more in-depth results**

478 The data clustering of bibliographic coupling analysis revealed four main clusters of WM
 479 research in the context of CE (Fig. 4 and Table 3). The fifteen most influential articles within each
 480 identified cluster, including CE perspectives on waste hierarchy, CE conceptualization and
 481 implementation, WM within closed-loop supply chains, and CE approach to the WM of plastics,
 482 are scrutinized to conduct the qualitative content analysis of our study in this section.

483 **4.3.1. Cluster 1: CE perspectives on the waste hierarchy**

484 The fifteen most influential articles from the last two decades of research making up this
 485 cluster on "CE perspectives on waste hierarchy" are relatively recent, including two articles
 486 published in 2015, two in 2016, five in 2017, two in 2018, and one in 2019. *Journal of Cleaner*
 487 *Production*, with six articles, has the largest representation in this cluster, followed by *Journal of*
 488 *Industrial Ecology*, and *Bioresource Technology*, with two articles each, and then *Environmental*

489 *Research Energy, Resources, Conservation & Recycling, Waste Management, and Journal of*
490 *Environmental Management*, with one article each. With different affiliations and coming from
491 diverse countries, various authors are also noticed, with Iacovidou being the only lead author
492 appearing two times within this cluster.

493 The first group of articles from this cluster can be drawn, including five articles sharing the
494 "generic" feature, meaning their findings or the framework and tools they develop could be applied
495 across sectors and businesses. While Van Ewijk and Stegemann (2016) discuss the barriers and
496 potential solutions to take waste hierarchy to the next level for achieving absolute reductions in
497 material throughput, the other authors from this group both question and develop the measuring
498 and monitoring instruments (Iacovidou et al., 2017a) for WM systems (Haupt et al., 2017) in a CE
499 perspective (Iacovidou et al., 2017b). More recently, Nižetić et al. (2019) started to discuss the
500 integration of smart technologies (e.g., smart cities and the Internet of Things) to achieve more
501 sustainable management of resources and waste.

502 The second group of articles from this cluster is focused on industrial sectors of high interest.
503 Among the ten articles from this second group, multiple specific sectors of utmost importance for
504 the future of enhanced WM practices are highlighted: (i) waste treatment, including sewage sludge
505 management solutions (Kacprzak et al., 2017; Smol et al., 2015), technologies for recovering
506 phosphorus from municipal wastewater (Egle et al., 2015), glass recycling (Blengini et al., 2012),
507 and waste electrical and electronic equipment at end-of-life (Mayers et al., 2005); (ii) textile reuse
508 and recycling (Sandin and Peters, 2018); (iii) MSW (Malinauskaite et al., 2017) and sustainable
509 urban planning for augmented resource management and valorization (Agudelo-Vera et al., 2011);
510 and (iv) concrete examples of waste valorization following the waste hierarchy (Mata et al., 2018),
511 such as specific lignocellulosic biorefineries converting biomass to bioethanol (Liguori and
512 Faraco, 2016).

513 These articles challenge the waste hierarchy to move "from waste to resources" (Kacprzak et
514 al., 2017) through concrete examples from the field. In fact, different but complementary CE
515 principles and loops are recommended depending on the industrial sector. For instance, sewage
516 sludge is increasingly seen as a valuable resource for energy generation (waste-to-energy) or use
517 in the construction industry, e.g., as feedstock for cement or concrete production (Smol et al.,
518 2015). Yet, these articles also highlight several gaps and margins for improvement to reach zero-
519 waste systems, such as the need for developing more waste-to-energy plants and technologies

520 (Malinauskaite et al., 2017) or the potential rebound effect and impact transfer caused by
521 inefficient reverse supply chains to collect and reuse products (Sandin and Peters, 2018),
522 necessitating optimized or better-dimensioned value chains.

523

524 **4.3.2. Cluster 2: CE conceptualization and implementation**

525 The majority of the articles from this cluster are literature review papers, both from a historical
526 (Winans et al., 2017) and a geographical perspective (Ghisellini et al., 2016; McDowall et al.,
527 2017; Su et al., 2013), as an attempt to conceptualize and clarify the CE (Merli et al., 2018; Reike
528 et al., 2018), for which an advanced and more integrated WM system is praised and required.
529 According to the research conducted by Merli et al. (2018), WM recently emerged as the most
530 relevant sub-concept of CE. In this line, the drivers and barriers of eco-innovation for enhanced
531 waste management from a CE perspective have been analyzed by de Jesus and Mendonça (2018).

532 The second group of articles from this cluster addresses the actual implementation of CE
533 principles in diverse key businesses, e.g., in the building (including both the construction and
534 demolition phases) industry (Gálvez-Martos et al., 2018), in the manufacturing industry (Lieder
535 and Rashid, 2016), within industrial symbiosis (Dong et al., 2013) or within the waste-to-energy
536 supply chain for augmented CE systems (Kushairi et al., 2018; Pan et al., 2015). Discussions on
537 the best practices from specific industries are particularly valued, such as in the building industry
538 (Gálvez-Martos et al., 2018) with a particular interest in the management of construction and
539 demolition waste through CE loops (Huang et al., 2018). Lastly, lessons learned from the
540 implementation of CE principles within WM systems are also highly valued by researchers and
541 practitioners (Bachmann, 2007; Pan et al., 2015; Singh and Ordoñez, 2016). It should be noted that
542 the management of plastic waste, which is also a significant challenge, is not mentioned yet in
543 clusters 1 and 2 and has its own cluster (cluster 4) and is addressed in sub-section 4.3.4.

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545 **4.3.3. Cluster 3: WM within closed-loop supply chains**

546 While waste mismanagement can lead to serious environmental issues, such as marine litter,
547 air, soil and water contamination, and hazardous waste leakage (Ferronato and Torretta, 2019), the
548 implementation of a CE can improve current solid waste management activities in developing
549 economies based on the principles of effective waste valorization and recycling (Ferronato et al.,
550 2019). To achieve material efficiency and reduce virgin material and industrial waste volumes

551 towards the CE transition, it is necessary to manage various barriers such as budgetary,
552 information, management, employee, engineering, and communication within the supply chain
553 (Shahbazi et al., 2016). An integrated WM system benefits from a closed-loop supply chain and
554 reverse logistics simultaneously (Islam and Huda, 2018; Pedram et al., 2017). The closed-loop
555 supply chain approach integrates both forward and reverse supply chains with a particular focus
556 on end-of-life products in the most environmentally friendly manner possible (Govindan and
557 Soleimani, 2017).

558 The significant impact of product design in terms of modularity, reparability, and recyclability
559 within the closed-loop supply chain network structure on the waste functions was highlighted by
560 Krikke et al. (2003). In this regard, reuse at a module level was identified as the most beneficial
561 recovery option, followed by material recycling and thermal disposal as the next best choices
562 (Krikke et al., 2003). Sustainable optimal design and planning for chemical processes and supply
563 chains focusing on energy efficiency and WM to minimize waste and energy requirements and
564 guarantee long-term sustainability is a significant challenge in supply chain management
565 (Nikolopoulou and Ierapetritou, 2012). Besides, a proper returns management not only in a specific
566 stage but also in the full lifecycle of products, as a key driver of value creation rather than a cost
567 of the business in closed-loop supply chains, can save the environment and support resource
568 efficiency (Krikke et al., 2013). The application of online mobile platforms within the supply chain
569 of MSW, where recycling practitioners or individuals can make appointments for on-site waste
570 collection, was evaluated as beneficial by Gu et al. (2019) in terms of overall environmental
571 performance for WM systems. Effective designing of closed-loop supply chains under uncertainty
572 is a highly complex and challenging task because of the interconnection of many factors such as
573 product variety, the short lifecycle of products, increased outsourcing possibilities, and
574 globalization of businesses (Vahdani et al., 2013). Lee and Chan (2009) developed an optimization
575 model to minimize the total reverse logistics cost and high utilization rate of collection points for
576 product returns, which improves the efficiency of logistics operations and supports reasonable
577 recycling economically and ecologically. Moreover, a closed-loop supply chain network was
578 designed by Özceylan et al. (2017) considering the end-of-life vehicles treatment, including
579 reverse operations such as shredding, recycling, dismantling, and landfilling to reintegrate the
580 reverse material flows into forwarding supply chains.

581 Recently, WM systems have been facing the challenge of E-waste, as one of the main end-of-
582 life products within the closed-loop supply chains, due to its severe adverse environmental and
583 human health impacts. Policy-makers and WM practitioners dealing with E-waste should
584 particularly consider all the disposition alternatives (i.e., recycling, remanufacturing, reuse and
585 repair) in an integrated manner within the closed-loop supply chain network design (Islam and
586 Huda, 2018). However, despite the increasing legal pressure on E-waste treatment policies,
587 efficient E-waste management due to the lack of an effective collection system and public
588 participation, as well as lax enforcement of regulations, is still in its infancy (Abdallah et al., 2012;
589 Lu et al., 2015).

590

591 **4.3.4. Cluster 4: CE approach to plastic WM**

592 Increasing environmental concerns regarding the accumulation of plastic waste in the natural
593 environment have pushed policy-makers to develop renewable alternatives and suitable WM
594 strategies during recent years (Payne et al., 2019). The European Commission has strongly
595 contributed to regulate production and consumption patterns on plastic and packaging in a CE to
596 support sustainability along the entire plastic value chain from producers to waste collectors and
597 recyclers (Foschi and Bonoli, 2019). Moreover, increasing the plastic recycling rate for both plastic
598 packaging and plastic from household waste has been highlighted as a priority in the European
599 Union strategy towards a CE (Eriksen et al., 2018). Adopting a new plastic economy based on the
600 CE principles, as an alternative to the linear economy, has gained momentum (Ellen MacArthur
601 Foundation, 2016) to reduce plastic waste and mitigate its damage to the environment and wildlife.
602 By applying a CE approach, plastic products are designed to be reused or recycled to reduce plastic
603 leakage into the environment before waste mismanagement occurs (Jambeck et al., 2018). As an
604 environmentally friendly alternative for fossil-based plastics, designing sustainable bioplastics
605 opens up opportunities to reduce carbon footprint at the production level and overcome resource
606 depletion by relying on the development of valorization protocols of renewable resources
607 (RameshKumar et al., 2020).

608 Payne et al. (2019) highlighted the significant role of using chemical recycling instead of
609 mechanical recycling for biodegradable plastics, such as polylactic acid, due to this approach's
610 potential for further integration of polylactic acid into a circular economy. Faraca and Astrup
611 (2019), in their study on plastic recyclability, highlighted the direct link between detailed

612 characteristics of plastic waste and recycling and showed that the recyclability of "High Quality"
613 plastic waste was 12–35% higher than "Low Quality" application. China's recent ban (late 2017)
614 on imports of low-quality recyclates has significantly affected the WM systems, which denotes the
615 importance of quality of resources at different parts of the materials, components, and products
616 characteristics lifecycle to facilitate the transitions towards resource efficiency (Iacovidou et al.,
617 2019). Van Eygen et al. (2018) denoted that setting recycling targets for plastic packaging in line
618 with the recycling process's actual output and maintaining the quality of output product is
619 necessary to 1) improve the circularity of plastic packaging and resource efficiency and 2) assess
620 the performance of the waste management system accurately. Moreover, closing the plastic loop
621 using mass-based recycling targets towards a CE transition is still challenging, and the focus of
622 WM strategies should be on decreasing impurities and losses through product design and
623 technological advancements (Eriksen et al., 2019) and minimizing the material degradation during
624 mechanical processes (Horodytska et al., 2018). The urgent need for regulating the standardized
625 labeling and sorting instructions for WM of bio-based plastics by governmental policy-makers and
626 material producers was outlined by Prieto (2016) to facilitate the CE transition. However, although
627 CE and sufficient recycling have been touted to managing plastic waste, over 50% of the plastic
628 waste has been exported to hundreds of countries across the world, which denotes the necessity of
629 adopting new policies to deal with the importation and exportation of plastic waste (Brooks et al.,
630 2018). Besides, hazardous waste requires more managerial consideration for the circulation use of
631 resources and increasing resource efficiency in developing a CE that targets waste reduction and
632 turning waste into a resource (Koop and van Leeuwen, 2017; Sakai et al., 2011).

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634 **5. Implications for research: directions for future studies**

635 According to the insights provided by the bibliometric, text mining, and qualitative content
636 analyses conducted, implications for future studies are presented in this section to address the third
637 research question:

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639 **RQ3.** What are the possible directions for future research on WM towards the CE transition?

640 After careful consideration, four lines of research were identified as potential research gaps
641 and directions for future studies to better position the WM research agenda in line with the CE
642 perspectives, sustainable environment, and human well-being as follows.

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- The possibility of using Information Technology (IT) tools with the advent of the Internet of Things (IoT) and Industry 4.0 has provided promising opportunities to improve the global WM systems towards a cleaner environment and sustainable CE transition, in particular in developed countries (Fatimah et al., 2020). For instance, developing a smart reverse system for efficient E-waste management based on interactive online maps of users' requests as an intelligent IT tool (Shevchenko et al., 2021), and applying IoT devices to monitor human activities and alert the WM centers to support taking appropriate actions (Alqahtani et al., 2020), are some examples of incorporating IoT-based tools into the current WM systems. However, research in this area is still in its infancy, and developing an inclusive, sustainable, and smart WM mechanism reinforced by IT tools and IoT facilities, especially in developing and less-developed countries, is still missing. Therefore, focusing on designing smart WM systems by expanding the application of IoT-based tools and devices to specifically contribute to (i) efficient waste collection and separation; (ii) supporting the long-term sustainability from environmental, social, and economic points of view; (iii) encouraging WM activities and practices from recycling to move up to the top of the waste hierarchy; and (iv) minimizing the adverse environmental implications, is a timely and promising direction for future research in the WM domain towards the CE transition.
- As depicted in Fig. 6, two main WM-related research streams have attracted attention recently. First, the biosphere side of a CE – with the keywords "biochar", "food waste", "biofuels", "circular bioeconomy" – presents significant research challenges that need to be addressed to reach a zero-waste agri-food ecosystem. Second, plastic WM (see cluster 4 in Table 3) and, more recently, the issue of single-use plastics have received more attention recently in the context of COVID-19 (Klemeš et al., 2020), where new trade-offs between environmental sustainability and health safety of waste and product recovery occur. Such trade-offs still have to be addressed, solved, or optimized by researchers. In this line, the resilience of reverse supply chains is a topic of the utmost importance in response to the disruptions and shortages caused by the pandemic (Singh et al., 2020; Yu et al., 2020). The unprecedented COVID-19 situation has led several sectors to both unsustainable WM and many disruptions all along the supply chain (Ranjbari et al., 2021;

674 You et al., 2020). While several authors (Sarkis et al., 2020; Wuyts et al., 2020) initiated
675 the discussion on lessons learned from the COVID-19 crisis for transitioning to sustainable
676 supply and production, further research is encouraged in the field of WM.

677 • Healthcare waste, as a matter of great concern for the environment, health, and well-being
678 due to its infectious and hazardous nature (Chauhan et al., 2021), needs more sustainable
679 and safe management. Voudrias (2018) argues that adopting a CE model for the current
680 healthcare WM as a whole would be unlikely. Putting the CE in place, dealing with
681 different streams of healthcare waste such as medical, clinical, and pharmaceuticals wastes
682 would also be challenging and need more effort and engagement by interdisciplinary
683 sectors. The main reason is that reusing, recycling, and recovering materials in this sector
684 are concerned with infectious, toxic, and hazardous sources, which expose the community
685 to health risks. According to the results of this study, the literature of WM towards
686 implementing the CE strategies lacks reliable and comprehensive research considering
687 waste generated by the healthcare sector. The existing studies in this domain are mainly
688 limited to suitable treatment methods for the safe disposal of healthcare waste (Chauhan et
689 al., 2021; Singh et al., 2021). Developing an inclusive CE model to incorporate different
690 activities and practices of healthcare WM, in particular by (i) exploring technological
691 advancement for recycling and recovery of healthcare waste, (ii) drafting national plans for
692 minimizing the waste generated and implementing the reuse strategy for non-hazardous
693 healthcare waste, and (iii) designing closed-loop supply chains for healthcare WM, is
694 highly recommended for further investigations in the future.

695 • As a conceptual and operational framework, the One Health (OH) approach aims to
696 integrate the collaborative efforts between interdependent sectors to link human health,
697 food-producing organisms, and the environment (Frazzoli and Mantovani, 2019) to achieve
698 optimal health for human, animals, and the environment. Although a considerable amount
699 of research has been conducted on the environmental impacts of different WM activities,
700 such as MSW landfills (Sauve and Van Acker, 2020), textile reuse and recycling (Sandin
701 and Peters, 2018), and recovering resources from food waste (Slorach et al., 2019), human
702 well-being and animal health, have been paid less attention. In particular, there is minimal
703 research considering the OH framework in the WM practices (Oliveira et al., 2019).
704 Therefore, conducting well-established research projects to involve the OH framework in

705 the waste hierarchy and planning and policy-making in the macro, meso, and micro levels
706 of WM systems for disease prevention and health promotion is highly recommended for
707 future research.

708

709 **6. Conclusions**

710 This study aimed to provide an inclusive map of WM research in the context of CE over the
711 last two decades by (i) mapping the evolution of the field over time; (ii) identifying the main
712 research themes and trends; and (iii) offering possible directions for future research to better
713 position the WM practices towards a CE. To achieve this, a mixed-method approach was followed
714 by conducting bibliometric, text mining, and content analyses on a total of 962 peer-reviewed
715 journal articles extracted from the WoS database, published from 2001 to 2020.

716 The obtained results unfolded four main clusters of WM research in the CE context, including
717 CE perspectives on waste hierarchy, CE conceptualization and implementation, WM within
718 closed-loop supply chains, and CE approach to Plastic WM. Besides, seven dominant research
719 themes of WM practices within the CE context, including bio-based WM, CE transition, E-waste,
720 MSW, environmental impacts and lifecycle assessment, plastic waste, and C&D WM, were
721 identified. Subject areas, such as OFMSW, plastic waste, C&D waste, food waste, biofuels,
722 circular bioeconomy, and single-use plastics, have attracted attention very recently, rather than
723 material cycles closed-loop supply chain, carbon emission, industrial ecology, and liquid waste.

724 The main findings of the present study shed light on the WM research agenda and considerably
725 contribute to the positioning of WM activities and practices aligned with the CE principles in the
726 future. The provided inclusive research landscape of WM systems, and its prominent highlight
727 patterns can serve as a base for a real-time guideline to lead further research areas and as a tool to
728 support WM policy-makers and practitioners to support the CE transition (which aims to minimize
729 the waste generation). Finally, four specific directions for the future research agenda of WM to
730 support the CE establishment, sustainable environment, and human well-being were proposed. The
731 provided research directions for the future particularly help with (i) establishing smart, sustainable
732 WM mechanisms employing IT tools and IoT-based facilities, (ii) alleviating the COVID-19
733 pandemic implications for plastic waste, (iii) developing a CE model for healthcare waste, and (iv)
734 converging the joint efforts of multidisciplinary sectors towards the optimal health for human,
735 animals, and the environment based on the OH approach.

736 This research is bound to have its limitations too. First, we clustered the research themes of
737 our dataset based on the bibliographic coupling of articles. Using other data clustering techniques,
738 such as co-citation analysis of articles, is recommended to further develop and compare the results.
739 Second, we considered only the WoS database in this study. Extracting valuable data from other
740 well-known scientific databases, such as Scopus, could provide more information in future
741 bibliometric analyses. And finally, our sample was chosen only among articles published in the
742 English language. Further investigation into non-English articles in this domain is recommended
743 to harmonize the research findings.

744

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