



## GLOBAL TENDENCIES IN WASTE MANAGEMENT CONSIDERING CIRCULAR ECONOMY PRINCIPLES

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### ABSTRACT

*With a growing urban population, that consumes an ever increasing amount of raw materials, the approach of the circular economy has gained interest from academia and decision-makers as a promising solution to urban challenges. This review aims to find out in how far the circular economy is reflected as a guiding principle of waste management in the academic literature during the past ten years. A selection of 28 full-text papers dealing with specific case studies have been analysed regarding their geographical scale (international, national, municipal, industrial) and the principles of reduce, reuse, recycle and recover. The results indicate a stronger consideration of the recycling and reuse principles on the national and municipal levels, as well as a strong research representation of the European Union and China. Furthermore, a number of technical papers dealing with the recover principle on the industrial scale have been identified. While the strong arguments for a move towards a circular economy are broadly confirmed, issues of social participation and technological progress are identified as future challenges.*

**Keywords:** literature review, waste management, circular economy.

## TENDÊNCIAS GLOBAIS NO GERENCIAMENTO DE RESÍDUOS CONSIDERANDO OS PRINCÍPIOS DA ECONOMIA CIRCULAR

### RESUMO

*Com uma população cada vez mais urbana que consome cada vez maiores quantidades de recursos, a economia circular tem ganhado interesse pelos acadêmicos e por tomadores de decisão como uma solução prometedora à solução dos desafios urbanos. Esta revisão bibliográfica visa descobrir em que medida a economia circular é refletida como princípio orientador no gerenciamento de resíduos nos últimos dez anos. Foi analisada uma seleção de 28 artigos completos que tratam de estudos de caso específicos quanto à sua escala geográfica (internacional, nacional, municipal, industrial) e os princípios reduzir, reutilizar, reciclar e recuperar. Os resultados indicam uma maior consideração dos princípios de reciclagem e reutilização a nível nacional e municipal, bem como uma forte representação da União Europeia e da China nas pesquisas. Além disso, foram identificados vários artigos técnicos relacionados com o princípio de recuperação à escala industrial. Embora os fortes argumentos em prol da mudança para uma economia circular sejam amplamente confirmados, as questões de participação social e progresso tecnológico são identificadas como desafios futuros.*

**Palavras-chave:** revisão bibliográfica; gerenciamento de resíduos, economia circular.

### 1. INTRODUCTION

The future of humanity is urban. Today most of the people live in cities and as the global population continues to grow, especially in developing countries (UN, 2015), this creates great pressures on urban infrastructures. There is a crucial need for proper housing, roads, water supply and sanitation. One of the main challenges is effective and proper management of these urban necessities. This

does not only mean the provision of goods and services to an ever-growing urban population but also includes dealing with the waste generated by them (DIAZ, 2017).

One way of looking at the product life-cycle and sustainable waste management is to move away from a linear “take-make-dispose” ideology into a closed loop, where garbage is not regarded as waste but as a potential resource (NELLES et al., 2016). This is the basic idea behind the “Circular Economy”. In brief, the circular economy approach proposes a new model of production and consumption that considers society’s impact on the environment as a whole (PEARCE; TURNER, 1990; WINANS et al., 2017). The concept derives from the study of nature and living systems, which are in constant transformation and regeneration. According to circular economy principles there are three main objectives in waste management: reduce, reuse and recycle (FENG; YAN, 2007; SAKAI et al., 2011; SU et al., 2013). This means avoiding waste generation in general, aiming towards high levels of reuse of materials and products, and recycling as much of the waste as possible. Some researchers also include a fourth dimension of material recovery (e.g. HU et al., 2011), which means using waste as products or secondary raw materials, expanding the concept to 4Rs.

## 2. OBJECTIVE

This review aims to look at global examples on how waste management is organised according to the circular economy ideology and how different areas around the globe implement circular economy principles into waste management. In the review we notice all the four dimensions fundamental to the circular economy (reduce, reuse, recycle and recover) as well as four different geographical scales of implementation (international, national, municipal and industrial). As part of the Federal University of Technology of Paraná’s research group on Public Policy and Dynamics of Territorial Development (PD2T), this literature review forms the basis for related interdisciplinary research on Brazilian municipal waste management practices.

The study parted from an interest in how far circular economy principles are applied in waste management on different levels. The goal is to analyse how these principles interact with current waste management practices and to what extent they are integrated into existing systems. The review aims to find out who is writing on these issues, where the research and case studies are located and what are the research focus areas and key findings.

## 3. METHODOLOGY

In order to evaluate current knowledge and understanding of the circular economy and waste management, a systematic review of academic literature was conducted. The review consists of both quantitative and qualitative analysis of academic articles published during the 10-year period from 2007 to 2017. An extensive literature search was carried out using the electronic databases Web of Science and EBSCO *Academic Search Premier*. Together these two databases provided access to a wide range of academic articles from several different disciplines, including technology, environmental science, economics and social sciences.

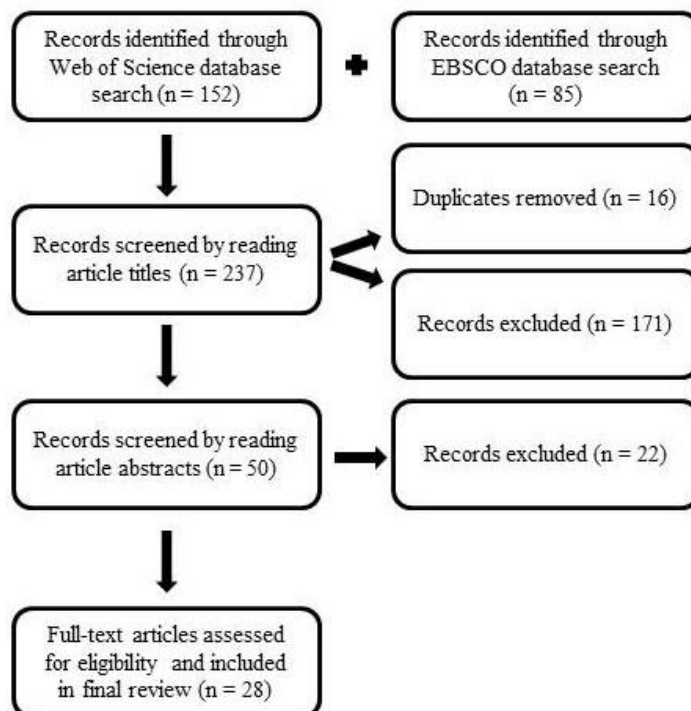
Three key criteria were defined to guide the selection of relevant publications: 1) the publication is a full-text academic article; 2) the article deals with waste management from a circular economy perspective; 3) the article presents a specific regional case study. The review included only academic articles and did not include conference publications or government reports. The article search was conducted in March 2017 so the research only covers articles published at that time.

In order to find as many articles as possible within the research context, the terms “waste management” AND “circular economy” were used as keywords in the databases. Within the selected time range (2007 to 2017) the total number of articles found in the combined database search was 237. By removing 16 duplicates, the net number was reduced to 221 articles. After an analysis of the titles, it was clear that at least 60 percent of these articles did not fulfill one or more of the selection criteria. Although the two main terms “waste management” and “circular economy” were both present in these articles, their relationship was not clear or the focus was not on waste management. Deleting

unintended results (abstracts or citations) further reduced the number of potentially relevant papers to 50.

Finally, a careful review of all 50 abstracts was performed by applying the three selection criteria defined above to each article individually. A total of 22 papers were removed because they failed to meet one or more of the selection criteria, for example 10 papers were not full-text academic articles (selection criteria 1) but reviews, conference reports or workshop papers. Two articles were omitted because they did not have a clear waste management perspective (selection criteria 2). A total of 10 articles failed to have a specific regional case study (selection criteria 3) and were therefore left out of the review. The remaining 28 papers were evaluated as full articles and were all included in the review. An overview of the selection process is presented in Figure 1.

Figure 1. Flowchart representing the selection of articles to include in the review. Illustration by the authors.



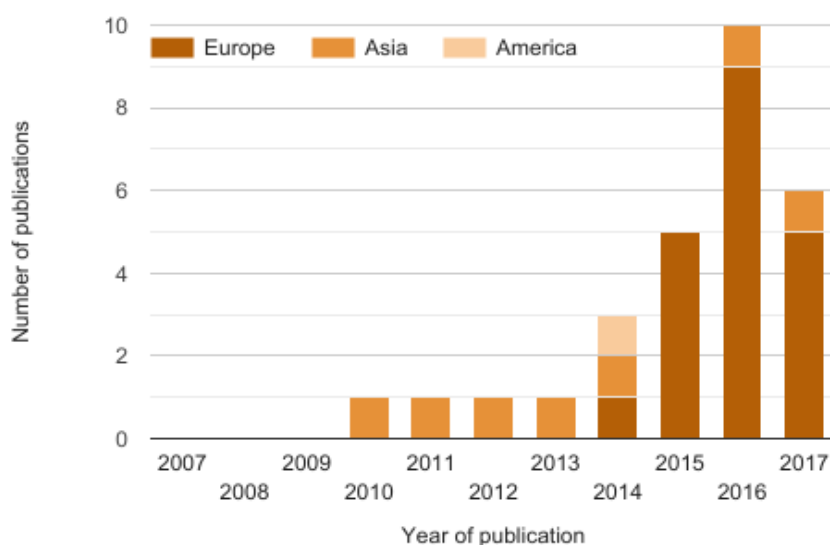
## 4. RESULTS AND DISCUSSION

### 4.1 AUTHOR AND YEAR PUBLISHED

A total of 90 authors contributed to the 28 papers. The vast majority of these (n=85, or 94 %) authored a single publication, while five authors (6 %) were named on two publications that met the selection criteria. This suggests that there are not yet any particular researchers focusing on the issue of waste management according to circular economy principles. Most of the articles were published in the research journals Waste Management (n=6, 21 %), Journal of Cleaner Production (n=6, 21 %) and Waste Management & Research (n=4, 14 %), the rest of the articles were published in several different journals, focussing on urban and environmental studies.

When examining the year of publication (Figure 2), it became obvious that the number of studies dealing with the selected themes, increased in the later half of the time period reviewed. While there were no papers published between the years 2007 to 2009 included in this review and only four articles published from 2010 to 2013, in the year 2014 the number increased to three and in 2015 to five articles. The last two years included in this review show the highest number of papers with 10 in 2016 and six in 2017, in spite of the review period only reaching until March 2017. This may reflect increased acknowledgement in recent years of the need to integrate circular economy principles into waste management and a change in direction from governments and other funding bodies toward applied studies that better facilitate the integration of these concepts. It may also reflect increased research attention directed to the issues of waste management and circular economy in general.

Figure 2. Geographical location of the case studies by year of publication. Illustration by the authors.



### 4.2 RESEARCH DESIGN

Two fundamental elements were analysed with respect to the research design of each study, namely the geographical area of the case study (i.e. where the data were collected, not the origin of the authors or the place of publication) and the methodology used. Regarding the geographical study area, the majority of the articles (n=21, 75 %) reported on case studies conducted in Europe, including three case studies in England, two in each Finland, Italy, The Netherlands and Serbia, and one case study in each Croatia, Germany, Ireland, Poland, Spain and Sweden. Also, three articles that were exploring the European Union (EU) or Europe in general were included in the review. In addition to this, seven articles (25 %) reported on case studies conducted in Asia, four of them located in China and one case study in each Bangladesh, Japan and Thailand. Only one article (4 %) had a case study located in America, selecting a study site in the United States.

When analysing the articles' case study locations together with the year of publication, it becomes clear that Asia (and China more specifically), has been a consistent in writing about circular economy and waste management in the past years. Over the 10-year period analysed, publications included research undertaken in Asia since 2010, while there has only recently started to be more articles with European case studies. From the year 2014 onwards there has been a steep incline in European research with the numbers of studies dealing with waste management and circular economy increasing every year. This may indicate that Europe and China are the most "dominant players" when it comes to sustainable waste management and circular economy and it is probable that the interest in Europe continues to grow as new policies and initiatives take place (see e.g. KAMA, 2015). The Global South (e.g. African or Latin American countries) were absent from the review, as were countries like Russia, Canada and Australia. This may be a result of the coverage of the databases selected or of different terminology and perspective used in the studies.

A majority of the articles (n=16, 57 %) applied primarily quantitative research methods in their case studies, including different kinds of data and material flow analyses, life cycle assessments and surveys. Other articles used more qualitative research methods (n=8, 29 %) like interviews and observations, or a combination of both quantitative and qualitative methods (n=4, 14 %).

### 4.3 RESEARCH FOCUS

The articles' research focus was analysed using two essential dimensions: first the implementation level of the case study and second the principles behind the circular economy approach. In respect to the implementation level, four different geographical scales were distinguished, namely an international, national, municipal and industrial level of implementation. Hereupon, the research focus was analysed according to the circular economy principles applied in the study, including the dimensions of reduce, reuse, recycle and recover. The review focusses on which scale and how these dimensions were employed in each of the case studies. It is important to notice that some of the articles applied not only one but several different scales and principles.

After a careful classification of the articles, it was found that a total of ten case studies (36 %) explored waste management on a "national" level, looking e.g. at former waste management practices (LI et al., 2013; SCHARFF, 2014; FARMER et al., 2015) or critical points for future improvement (ILIĆ; NIKOLIĆ, 2016; LIIKANEN et al., 2016; STEVANOVIĆ-ČARAPINA et al., 2016). Nine studies (32 %) explored waste management on an industrial level, focussing either on a specific waste management process of a certain end product (KULCZYCKA et al., 2016; VIANI et al., 2016; SANTAGATA et al., 2017) or on a particular type of industry (USAPEIN; CHAVALPARIT, 2014; GU et al., 2016; LASO et al., 2016). Another eight studies (29 %) dealt with waste management on a municipal level, exploring e.g. the challenges and opportunities related to waste management in a particular city (WANG; GENG, 2012; RIBIĆ et al., 2017). Only three of the studies had an international implementation level, looking waste management either in the context of EU (KAMA, 2015; JIMÉNEZ-RIVERO; GARCÍA-NAVARRO, 2017) or the Nordic countries (RICHTER; KOPPEJAN, 2016).

In regards to the dimension used, the majority of studies (n=16, 57 %) dealt with "recycling", including for example studies looking at electronic waste recycling (GU et al., 2016) or post-consumer gypsum recycling (JIMÉNEZ-RIVERO; GARCÍA-NAVARRO, 2017). The second most commonly used dimension was "reuse" (n=13, 46 %), which was applied e.g. by Li et al. (2013) who investigated the comprehensive reutilisation of resources in China and Park and Chertow (2014) who developed a quantitative reuse potential indicator to aid decision-making to manage wastes as resources. The dimension "recover" was applied in nine studies (32 %) including a study investigating how to best recover value from used laryngoscopes (VIANI et al., 2016) and one research describing technologies to recover phosphorus from municipal wastewater (EGLE et al., 2015). Finally, the dimension "reduce" was mentioned in eight case studies (29 %), e.g. in landfill reduction practices in The Netherlands (SCHARFF, 2014). From these articles only one covered all the four principles

of circular economy (HU et al., 2011), while four articles applied the 3R ideology (WANG; GENG, 2012; USAPEIN; CHAVALPARIT, 2014; FARMER et al., 2015; ILIĆ; NIKOLIĆ, 2016). When cross-examining the implementation level together with the circular economy principles applied in the studies (Figure 3), two major patterns can be identified. First, recycling stands out as the most studied dimension regarding waste management according to circular economy principles. Secondly, more studies use the national implementation level than any other geographical scale, when examining waste management. In general, the majority of the articles are strongly technically oriented and interested either in how to improve sustainability and efficiency of waste management or on how to recover value from waste.

Figure 3. Distribution of authors in the analysis matrix. Illustration by the authors.

	reduce	reuse	recycle	recover
inter-national		Kama, 2015	Jiménez-Rivero & García-Navarro, 2017; Kama, 2015; Richter & Koppejan, 2016.	
national	Farmer et al., 2015; Ilic & Nikolic, 2016; Oldfield et al., 2016; Scharff, 2014.	Farmer et al., 2015; Ilic & Nikolic, 2016; Li et al., 2013; Oldfield et al., 2016; Park & Chertow, 2014.	Farmer et al., 2015; Ilic & Nikolic, 2016; Liikanen et al., 2016; Sahimaa et al., 2015; Stevanovic-Carapina et al., 2016; Ueberschaar et al., 2017.	Ueberschaar et al., 2017
municipal	Ilic & Nikolic, 2016; Wang & Geng, 2012.	Dururu et al., 2015; Geng et al., 2010; Ilic & Nikolic, 2016; van der Hoek et al., 2017; Wang & Geng, 2012.	Dururu et al., 2015; Geng et al., 2010; Ilic & Nikolic, 2016; Ribić et al., 2017; Wang & Geng, 2012.	Egle et al., 2015; Islam, 2017; van der Hoek et al., 2017.
industrial	Hu et al., 2011; Shahbazi et al., 2016; Usapein & Chavalparit, 2014	Hu et al., 2011; Laso et al., 2016; Usapein & Chavalparit, 2014.	Gu et al., 2016; Hu et al., 2011; Richter & Koppejan, 2016; Usapein & Chavalparit, 2014.	Hu et al., 2011; Kulczycka et al., 2016; Laso et al., 2016; Santagata et al., 2017; Viani et al., 2016.

#### 4.4 KEY FINDINGS

The literature generally suggests that some of the most crucial steps a society has to take in order to move towards circular economy and zero waste is the adoption of the “reduce, reuse, recycle” (3R) ideology in all manufacturing and material management (e. g. ISLAM; 2017). This ideology has been effectively put into action especially in the EU, where the member states increasingly indicate the circular economy as a political priority (RIBIĆ et al., 2017). Researchers agree that the adoption of the 3R ideology would result in a reduced waste quantity on landfills and create new green jobs (USAPEIN; CHAVALPARIT, 2014; ILIĆ; NIKOLIĆ, 2016). Some authors suggest to include the fourth dimension of material recovery (HU et al., 2011), so using wastes as potential secondary raw materials. According to Hu et al. (2011) and Santagata et al. (2017) waste recovery can help to save money while reducing pollution at the same time. These findings are also supported by Islam (2017), who highlights the role of waste-to-energy recovery in minimising the greenhouse gas emissions. In cities, local governments are facing big challenges as people increasingly demand for better quality of life with increasing consumption rates, while at the same time, available space for landfills is getting limited (WANG; GENG, 2012). Sahimaa et al. (2015) and Liikanen et al. (2016) suggest that planners need to be provided with updated classification systems in order to better assess municipal solid waste. Park & Chertow (2014) with “the reuse potential indicator” introduce such a quantitative tool to assist decision-making. Wang and Geng (2012) point out that these analyses

must however take into account local variables such as the level of industrialisation, income and consumption levels.

Several authors also agree that for reducing the environmental impacts of cities, waste reduction must be among the first initiatives (OLDFIELD et al., 2016). Here, not only new technologies but also valorisation of industrial and food waste can prevent loss of resources and be more environmentally sound than incineration and landfilling (LASO et al., 2016; JIMÉNEZ-RIVERO; GARCÍA-NAVARRO, 2017). For the urban landscape van der Hoek et al. (2017) and Geng et al. (2010) point out the potential of urban symbiosis and closed urban cycles that could benefit the recovering of resources. According to van der Hoek et al. (2017) the implementation of waste reuse and recovery initiatives result in both economic and sustainability benefits. Researchers like Egle et al. (2015) point to the newly created markets that have emerged from material recovery. The potential of Waste Electrical and Electronic Equipment (WEEE) is recognized by several authors in this review (e.g. UEBERSCHAAR et al., 2017) and has even led to a re-territorialization of this particular type of waste in the EU (KAMA, 2015). China, as one of the world's largest manufacturers has at the same time become the largest recipient of WEEE, which according to Gu et al. (2016) has stimulated the formalisation and enforcement of environmental standards. Li et al. (2013) also claim that these developments have already led to a reuse rate of almost 60% of all solid waste, providing in 2010 one fifth of the total resource requirements in that country. In addition to material recovery, collection and recycling can create opportunities to reuse valuable materials. Several authors are quite optimistic about the role technological innovations will play in the development of a more circular economy (UEBERSCHAAR et al., 2017; KULCZYCKA et al., 2016; STEVANOVIĆ-ČARAPINA et al., 2016).

However, Viani et al. (2016) and Shahbazi et al. (2016) affirm that it may not be necessarily an absence of appropriate technologies, but limited communication, a lack of engagement or end markets that inhibit the intended circling processes. Richter and Koppejan (2016) remind that even when collection and recycling rates are high, many opportunities for further improvement remain unexplored. It is also important to notice, that we cannot disconsider consequences of reforms like the foreclosure of landfills which has resulted in high societal costs in The Netherlands (SCHARFF; 2014) or in an unintended increase in incineration in England (FARMER et al., 2015) and a general tendency of the use of this method in Japan (GENG et al., 2010). These authors point to the importance of political consensus on the preferred directions and concurrently criticise the lack of clarity of some policies.

What comes to policies, actors and public engagement, several of the authors in this review point to the crucial importance of the social side of recycling, as it is decisive in the actual day-to-day practice of those principles. According to van der Hoek et al. (2017) municipal companies can be important players in helping cities on their path towards a resilient and sustainable future. Jiménez-Rivero and García-Navarro (2017) point to the crucial role of governments in strengthening enforceable legislations and regulatory frameworks, to which Ribić et al. (2017) add the need for permanent and comprehensive education of the public concerning recycling and composting. Ribić et al. (2017) also hold that systemic change is only possible through an analysis from a systematic perspective. Dururu et al. (2015) see voluntary and community sector organisations as key agents in the shift towards circular economy as these organisations' role is pivotal in engaging and empowering the society. Finally, waste management requires a collaborative approach, with strategic partnerships between government, local authorities, experts, and the general public (RIBIĆ et al., 2017).

#### 4.5 DISCUSSION

This review has presented an overview of ten years of research (2007 to 2017) addressing waste management according to circular economy principles from 28 studies from 16 different countries. While it has become clear, that an increasing urban population constantly demanding for better quality of life and consuming an ever increasing amount of raw materials cannot sustain itself in the long term, this review shows that there are already countless initiatives moving towards a more

sustainable, circular economy, where garbage is not just wasted but reused, recycled and recovered. Most of the studies included in the review found that managing waste according to circular economy principles is environmentally, socially and financially beneficial for the society.

According to the review findings, circular economy has started to strengthen its position as a guiding ideology in the research of sustainable waste management most strongly in Europe and China within recent years, as previously confirmed by other researchers (e.g. APPELQVIST et al., 2015). Many studies clearly get their motivation and validation from political priorities in the EU, Japan and China. It strikes that there has been no noticeable move towards circular economy by developing countries yet, as this would probably be economically and environmentally beneficial. Nonetheless, it becomes clear that while there are several strategies and regulatory instruments already in place, they are not necessarily effective. According to the review, this is usually caused by the lack of political will, financial capacity, public participation or insufficient resources.

In order to solve these complex challenges, governments have the most crucial role in developing stronger waste legislation and clear regulatory frameworks that obligate municipalities to take concrete actions. Ultimately however, these initiatives will not have the desired impact without the change of consumption habits at the individual level. So reforms need to take place on all fronts. While these developments might be intensified by innovation and the development of new technologies that facilitate reduction and harnessing through more efficient processes, it cannot be forgotten that the solutions to our waste problems are profoundly societal and as such need to take place in fairly negotiated and democratic processes in order to give the desired results.

## 5. CONCLUSION

The review provided in this paper furthers our understanding of the current state of knowledge and demonstrates circular economy becoming a guiding principle in a waste management context. After analysing the articles included in the review, it becomes clear that waste management according to circular economy principles needs more comprehensive and multidisciplinary research approaches. Although the conceptualisation of circular economy and research on sustainable waste management have come a long way as individual domains, there is a need for greater integration of these two themes. The results of the study make clear that the dimensions of recycle and reuse have already a strong standing in policy and research considering waste management, while recovery is only starting to establish its role from a technical perspective. To be most effective, the research findings should be presented with consideration of practical applications for policy makers and planners alike.

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