International Journal of Sustainable Development and Planning
Vol. 18, No. 11, November, 2023, pp. 3401-3417
Journal homepage: http://iieta.org/journals/ijsdp

A Comparative Bibliometric Analysis on Plastic Waste Recycling

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https://doi.org/10.18280/ijsdp.181106

Received: 1 May 2023
Revised: 14 August 2023
Accepted: 18 September 2023
Available online: 30 November 2023

Keywords:
linear economy (LE), Circular Economy (CE), degrowth economy (GE), biliometric analysis, VOSviewer, plastic waste, recycling

ABSTRACT

The aim of this study is to explore the application trend of the circular economy and research on plastic waste recycling by comparing results from selected databases. The methodology involves developing a bibliometric study based on data from Scopus and the Web of Science Journals & Country Rank, spanning from 2014 to 2023. A total of 2,083 articles were retrieved from these two research databases, with 1,108 and 975 articles coming from Scopus and WoS, respectively. Descriptive bibliographic maps and strategic charts, generated by OriginPro, Excel, and VOSViewer, are presented. The Circular Economy (CE) is a model that eliminates waste, adopts sustainable practices, closes loops in industrial ecosystems, and turns end-of-life products into resources for others. This stands in contrast to the linear economy, which disposes of waste through landfill or incineration. Currently, plastic production is still supported by a resource-intensive paradigm that decouples economic growth from resource consumption. The annual consumption of plastic materials and fossil fuel is projected to triple by 2050, a trend that has attracted significant attention. The introduction of CE has drastically reduced resource consumption. This study compares the Scopus and Web of Science databases regarding current plastic use and recycling of plastic waste. Moreover, it identifies the future contribution of the degrowth economy in managing plastic waste for recycling.

1. INTRODUCTION

Although plastic is a necessary component of the modern economy, contributing significantly to food packaging [1, 2], road construction [3], and the prevention of infectious diseases [4, 5], its current production, utilization, and disposal methods do not reap the financial benefits of a more circular approach and have significant negative environmental impacts [6, 7]. As a result, there is growing concern about the environmental issues related to the manufacture, use, and disposal of plastics and the plastic waste accumulating in the oceans yearly [8, 9]. Plastics help the economy expand [10], but their current manufacturing and use habits, following a linear “take-make-use-dispose” model, are major contributors to waste, depletion of natural resources, environmental degradation, climate change, and poor human health [11]. Climate change negatively impacts human health [12].

It is estimated that only 567 Mt of the 6300 Mt of plastic waste produced globally between 1950 and 2015 was recycled [13], with India estimated to have the highest plastic waste recycling rate, approximated at 60% [10]. Out of the 25 Mt of post-consumer plastic waste generated in the EU, only around one-third was recycled. China produced 63 million tons of plastic waste in 2019, about a third of which was recycled or buried, and the rest incinerated. The remaining 7% of this material was released into the environment [14]. In 2015, the world produced 7.8 billion tons of plastic, more than one ton of plastic for every living person [15]. The volume of waste that can remain in the natural environment for ~1,000 years after purchase has significantly increased. Many plastic packaging items and commodities are used only once before being disposed of as waste. Ninety percent of the plastic waste produced between 1950 and 2015 ended up in landfills or other areas of the environment, and only about 10 percent of that was recycled [10]. In addition to a lack of recycling infrastructure, many plastic materials make recycling unprofitable, contributing to the low recycling rate. Unless current consumption patterns and waste disposal techniques change, around 12 billion tons of plastic waste will end up in landfills and the environment by 2050 [16].

In 2016, the Europe and Central Asia region produced 395 million tons of waste, or 1.21 kg per person per day [17]. Only 33% of waste materials are currently recycled or composted, although around 75% of this waste has the potential to be recovered through these methods. This amount of waste damages the area in which it is located, causes disease among the population, lowers air quality, and accelerates climate change. Inefficient waste management and treatment processes generated 1.6 billion tonnes of carbon dioxide equivalent (CO_2-eq) gases in 2016, accounting for approximately 5% of global emissions [18].

Circular Economy (CE) models present a new paradigm contributing to the solution for this problem. CE models aim to maintain the added value of products for as long as possible and minimize waste, keeping resources within the economy when products no longer serve their intended purposes, so that materials can be reused and generate additional value [8, 19-21]. A fundamental shift in thinking about the production, consumption, and recovery of resources has spurred the global rise of CE. As a result, CE is defined in various ways in both scientific and grey literature [22, 23]. Plastics were identified as a priority in the CE Action Plan adopted in Europe in 2015, leading to the development of a strategy that considers the entire life cycle of plastics and attempts to address the problems they cause along the value chain. The European Commission's (EC) goal is to ensure all packaging materials are biodegradable by 2030. In 2017, the EC announced that its focus would be on the production and consumption of plastics [22]. Thus, circular business models generate more value from each natural resource unit than traditional linear models [24, 25].

Resource scarcity, inefficient production and consumption, and the effects of climate change contribute to global challenges and constraints [26]. In theory, avoiding plastic waste is the best approach to manage it. However, reuse is the next best option for managing plastic waste in a system where it is produced [27]. The circular economy greatly interests various stakeholders, including the production industry, government, and post-consumers, as it enables sustainable development [28]. Plastic materials are increasingly preferred over conventional materials like glass, ceramics, wood, etc., particularly as packaging materials [29, 30]. Polyethylene terephthalate (PET) is widely used and considered the most recyclable plastic for food packaging [31, 32]. It is more suitable for recycling because, among other reasons, it is less prone to absorbing post-consumer contamination than other plastics, such as polyolefins [30]. Unfortunately, proper disposal of PET is often overlooked, disregarding its long-term effects on the environment and human health [33].

Circular Economy (CE) models have emerged as a new paradigm contributing to the solution of this problem. CE models aim to maintain the added value in products for as long as possible and minimize waste, retaining resources within the economy when a product no longer serves its purpose. This approach allows materials to be reused and generate additional value [8, 19-21]. A fundamental shift in thinking about resource production, consumption, and recovery systems has accelerated the global adoption of CE. As a result, CE is defined in various ways in both scientific and grey literature [22, 23]. Plastics were identified as a priority in the CE Action Plan adopted in Europe in 2015. Consequently, a strategy was developed that examines the entire life cycle of plastics and attempts to address the problems they cause along the value chain. The European Commission's (EC) goal is to ensure all packaging materials are biodegradable by 2030. In 2017, the EC announced its focus on the production and consumption of plastics [22]. Thus, circular business models create more value from each unit of natural resources than traditional linear models [24, 25].

Resource scarcity, inefficient production and consumption, and the effects of climate change contribute to global challenges and constraints [26]. In theory, the best way to manage plastic waste is to avoid generating it. However, in a system where plastic waste is inevitable, reuse is the next best option [27]. The circular economy holds significant interest for various stakeholders, including the production industry, government, and post-consumer sectors, as it enables sustainable development [28]. Plastic materials continue to outperform conventional materials like glass, ceramics, wood, etc., especially as packaging materials [29, 30]. Polyethylene terephthalate (PET) is widely used and considered the most recyclable plastic for food packaging [31, 32]. It is particularly suitable for recycling because, among other reasons, it is less likely to absorb post-consumer contamination than other plastics, such as polyolefins [30]. Unfortunately, the proper disposal of PET is often overlooked, without considering the long-term impact this has on the environment and human health [33].

These developments indicate that a significant portion of the world is still in the early stages of embracing the circular economy. The circular economy has a long tradition in packaging, especially for PET mineral water and soft drink bottles [34]. In light of this, this research leverages the databases of the two most populated regions to analyze and compare the annual number of publications, some of the influential journals and authors, and the primary areas of interest on which these publications are based.

The aim of this study was to compare the publication coverage of Scopus and WoS in terms of author and co-authorship levels on the recycling of plastic waste, and examine how the promotion of the circular economy of plastics could be enhanced. This paper provides readers with an up-to-date overview of the circular economy, highlighting the main authors, country-specific publications related to plastic waste recycling and the circular economy.

2. LINEAR ECONOMY

In a linear economy, resources are extracted to produce synthetic items [35]. When these products reach the end of their lifespans, they are typically discarded as household waste and often end up in landfills or polluting the environment [36-38]. This linear economic framework supports the conventional waste management approach, characterized by the collection of mixed waste and the landfilling or incineration of waste generated by households, businesses, and agricultural activities, with no resource recovery [39]. Figure 1 illustrates this linear economic model.

In 2013, the Ellen MacArthur Foundation stated that the existing economic structure originates from consistently unequal income distribution by geographical region. Industrialized nations have experienced a surplus of material resources and energy as resource consumption is concentrated mainly in the most developed regions, and material inputs are increasingly sourced from the global market. In this arrangement, material costs were relatively low compared to labor costs [40].

Consequently, producers were incentivized to develop business models that minimized labor costs and relied heavily on the efficient use of raw materials. The stronger their competitive advantage, the more resources they could allocate to developing human capital [41]. A collective neglect of recycling, reuse, and careful waste management is a natural outcome of cheap labor and inexpensive materials. Regulatory, accounting, and tax standards that failed to hold producers accountable for external costs have perpetuated this system, as producers have little incentive to consider the wider costs of their actions [42]. The formal approval process for production components typically favors existing methods over radical changes and rethinking of fundamental concepts, creating a natural lock-in inertia within the system. The linear economy is the outcome of this economic strategy. It can be succinctly summarized as "Take, Make, Dispose": extract the resources you need, manufacture the goods you will sell and profit from, and discard all else, including items that have reached the end of their useful life [20].

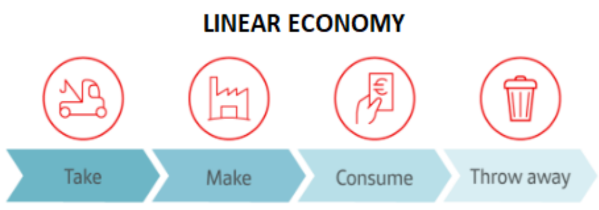

Figure 1. The linear economic model [43]

According to statistics, the global economy is only 8.8% circular. The burning of fossil fuels, which has fueled this expansion, has led to an average global temperature rise of 1.2℃ and could result in a 3.7℃ rise by the early 22nd century without global intervention. Many climate change impacts, such as more intense and frequent storms and floods, prolonged droughts, rising sea levels, increased extreme heat events, altered freeze-thaw patterns, and severe wildfires, are already being experienced in places like China, Turkey, Australia, and the United States [44].

The foundation of linear economics is the misconception that new materials, particularly virgin plastic, are less expensive than environmentally friendlier substitutes. This notion stems from decades of oil and gas industry subsidization and an inability to adequately account for the hidden costs associated with the production, use, and disposal of virgin material through landfilling or incineration. External costs, such as those resulting from material spills or local habitat contamination, are currently not factored into disposal cost calculations. Dependence on single-use plastics and the accumulation of plastic waste have serious climate, social, and economic consequences. To establish a circular economy, the use of recycled or reused materials should be encouraged through the implementation of new market incentives for recycling and reuse developments, as well as public-private matching subsidies. Materials should be designed with recycling in mind, and consumers need consistent, easy access to a reliable recycling system [45].

Basically, the accumulation of plastic in the ocean serves as an example of how this fatal design flaw combined with linear economics has become a significant source of plastic waste. It is worrying to note that if current trends continue, the amount of plastic waste in our oceans will increase from an estimated 200 Mt today to 280 Mt by 2030 [35]. This economy is hostile to the plastics industry and needs to be completely discouraged by using alternative economies to eliminate plastic waste pollution as a result of the linear economy along the plastics value chain.

Meanwhile, in a circular economy, items are made durable, reusable, and recyclable, and resources for innovative products are sourced from older ones. Everything is recycled back into raw materials, used as an energy source, reused, remanufactured, or, as a last resort, discarded as much as possible [46]. The circular economy, an alternative model to the linear economy, is based on these fundamental ideas:

- Reduce plastic waste and pollution through product design,
- Retain resources and products in use,
- Regenerate and maintain natural systems.

A clear opportunity, therefore, exists for industry to adopt a new plastics economy, underpinned by the core principles of the circular economy, to enhance both socio-economic performances across the supply chain, whilst drastically reducing plastic waste and, with it, the subsequent negative environmental impact [35, 47].

There is an economic system that aims to maximize resource use and minimize waste. A closed-loop system minimizes resource use, waste, emissions, and energy losses by slowing down, closing, and expanding the energy and material cycles. This can be done through design, reuse, upcycling, and recycling. In contrast to the classic linear economics of the take-make-dispose-manufacturing model, the regenerative approach emphasizes sustainability. Since the same output can be produced with fewer raw materials, for example, the circular economy is not in conflict with economic growth [48-50].

3. CIRCULAR ECONOMY

To replace the inefficient linear economic model with a cyclical ecosystem, Boulding (1966) proposed the creation of CE. Although Bouldings' (1966) cyclical economic model is very flexible, it encouraged further conceptual growth of sustainability. The self-renewing economic architecture with a spiral cycle (or closed cycle) was first proposed by Stahel in 1982 and further expanded by Stahel in 2010 to the concept of a performance economy. The core of the performance economy (Table 1) is the reinterpretation of the goals of the economies such as in the focus, initiatives and business models that are currently gaining ground [20, 51]. Figure 2 shows the circular economy model.

In a circular economy as shown in Figure 3, we strive to prevent significant waste by reusing items resulting from repairs as much as possible and then recycling them to restart the cycle. The circular economy is transitioning to one that uses less energy and raw materials. The waste generated by the design process is integrated into a spiral reuse cycle. By implementing appropriate green technologies, waste from one industrial process is used as raw materials for another [49].

Summarily, the Ellen MacArthur Foundation highlighted that in the plastics sector, the following goals of a circular economy are to be achieved: stopping the entry of plastics into the environment, especially into rivers and seas, increasing the profitability of plastic recycling and reuse and at the same time separating the production of plastics from fossil fuels and integrating renewable energy sources are further goals [7, 10, 52].

Table 1. Circular economy versus linear economy [53]

Features	Circular Economy	Linear Economy
Focus	Eco-effectiveness	Eco-efficiency
Initiatives	Reduce-reuse-recycle	Take-make-use-dispose
System limits	Long-term, multiple life cycles	Short term, from purchase to sale
Business plan	Focuses on services	Focuses on products
Reuse	Cascading, high-quality recycling & upcycling	Downcycling

a) Making plastics with different biofuels

Greenhouse gases such as CO_2 and methane are examples of substitute raw materials [16, 54], and sewage sludge, food products, naturally occurring biopolymers, starches, and cellulose is examples of bio-based sources. Some polymers can be made using safe and biodegradable elements. In addition, eco-friendly substitutes for flame retardants have now been created that could eliminate the use of some hazardous chemicals in the manufacture of plastics [55-58].

b) Use recycled plastic as a resource

It has been widely established that plastic waste may be collected and recovered for remanufacturing into new items with higher value, including bricks and composites, furniture, garments, and footwear [59, 60]. Although there are drawbacks to the latter method, plastic waste has also been turned into liquid fuel and used as fuel in a waste-to-energy cycle [61]. The petrochemical constituents of conventional plastics can be recovered through chemical recycling and used to make new plastics, other chemicals, alternative fuels, or new compounds [62]. Recyclable and reusable plastics that can be chemically produced indefinitely have been successfully created in a recent study [63]. In addition, they hypothesize that bacteria and caterpillars can degrade polyethylene plastic, which accounts for a significant number of manufactured plastics worldwide [64, 65].

c) Improve the durability, reusability, and waste reduction of plastic manufacturing processes and products by designing them with end-use, asset recycling, and environmental management in mind

This requires a lifecycle approach that includes cleaner production, reducing the use of single-use plastics and other avoidable plastics, designing products for reasonable lifespans and longer uses, and for easy segregation, repair, upgrade, and recycling, removing toxic materials and the redesign of products to prevent the release of microplastics into the environment. This is evident in the elimination of microplastics from personal care products like toothpaste and shampoo and in the development of tires and clothing that wear out less [66]. Also redesigning is the elimination of single-use plastic bottles through mass distribution of cleaning and personal care items in reusable plastic containers. Returnable beverage bottles, such as those with returnable bottle systems and refillable bottles, are another example of a product that can replace single-use bottles and reduce greenhouse gas emissions while being more cost-effective [67, 68].

d) Enhanced collaboration between business and customers to increase knowledge of the benefits of moving away from non-essential plastic use and throwaway culture, promoting recycling, and increasing the value of plastic products

The climate and environmental benefits of recycling plastic waste through smart manufacturing have been underlined in several studies [69, 70]. Households can participate in the symbiosis process by improving waste collection systems and developing creative, efficient take-back programs [71, 42]. The collaborative efforts of the Kriki4Shore program, which turned rubbish collected from South African beaches into beach cricket sets for nearby communities. Each beach cricket set (bat, ball, and wicket) is made from waste collected from South African beaches, including plastic and bottle caps. The collections are handcrafted from junk or molded from 60% recycled plastic. The project seeks to educate the community about the value of waste and provides jobs for waste collectors and artisans in coastal areas [72].

e) Promoting items as services and promoting the sharing and subletting **of plastic products are sustainable business approaches worth supporting**

Technological options will encourage sustainable alternative materials to plastics, and innovative packaging and recycling technologies are available worldwide, focusing on these technologies from Asia. Also, plastics value chains in the target countries and their regulatory framework and stakeholders in the industry [73].

f) Building reliable information channels

The creation of compatible material flow accounts in a global database, the promotion of knowledge about the environmental costs and impacts of the use of material resources throughout a material life cycle, and the promotion of the creation of reliable international indicators on the cycles of materials and products, metrics that material for production with linking material flows, and indicators linking material flows to waste streams [74]. The Resource Efficient and Cleaner Production Network or RECPnet is an international network that promotes resource-efficient, cleaner production and encourages collaboration by transferring relevant information, expertise, and technology [10].

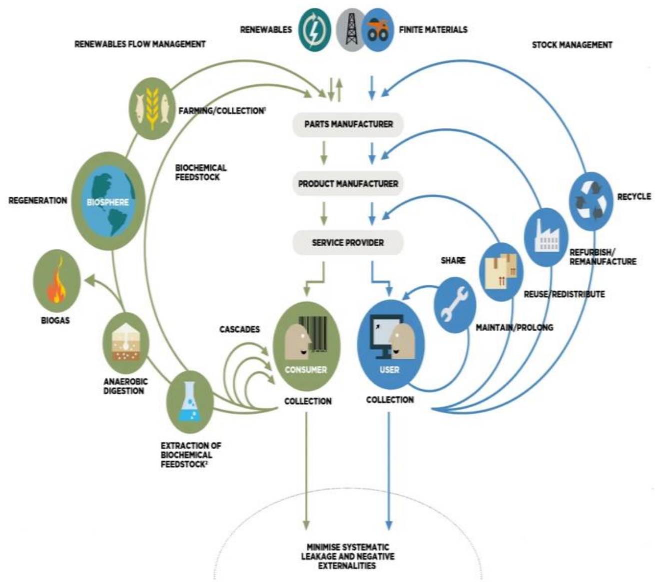

Figure 2. Summary of the circular economy [75]

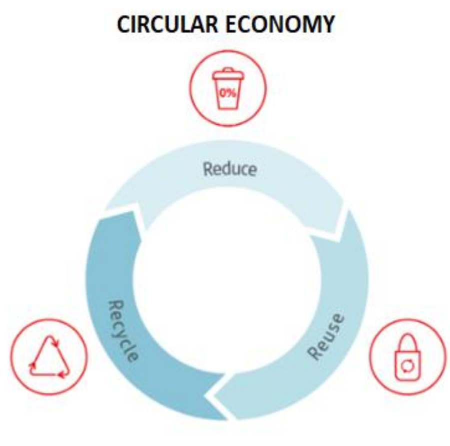

Figure 3. The circular economy model [43]

g) Policymakers have taken economic and regulatory action to address the harmful effects of unsustainable production and use of plastics

With the current low oil prices [76], which make it even harder to overcome the challenges of achieving the circular economy [77], these policies would tend to favor fuels [78]. The use of substitute materials, less hazardous sources, waste prevention, and the promotion of recycling and reuse would be encouraged if the costs of environmentally unfriendly production and use were considered [79, 80]. Necessary policy actions include recycling targets, extended product stewardship, container deposit laws, mandatory regulations and requirements for circular/eco-design, government procurement policies, bans on incineration and landfill, and bans on specific plastic product's single-use plastic bags [81, 82].

Conclusively, the main goals of the CE were to increase recycling and stop the loss of valuable materials, boost job growth and economic development, and show how to achieve new business models, the elimination of toxic chemicals, industrial symbiosis and the transition to zero waste of these goals and to reduce greenhouse gas emissions and other negative impacts on the environment.

4. DEGROWTH ECONOMY

The circular economy is essential [37] but an insufficient part of the response to the global plastics crisis [7]. While it would be ideal, producing all plastics from alternative raw materials would not be possible due to possible negative impacts on human food sources, the environment, or public health [10]. Existing improvement initiatives must be complemented and guided by focused, international collaboration, fit for purpose and opportunity, to go beyond small and incremental improvements and achieve systemic change towards the New Plastics Economy. Since no such program currently exists, it must be set up and implemented by a separate coordinating vehicle [7]. To understand the socio-economic and environmental impacts of, for example, using land resources to produce bioplastics instead of food, thorough life cycle analyses are required [83].

Additionally, there is no accepted definition of what constitutes a plastic as biodegradable; Using such polymers would not reduce the amount of plastic entering the environment or the associated chemical impact [84]. Many avenues could be taken to achieve this, including removing excessive plastic packaging from goods such as food, banning the use of tiny plastic particles in personal care products, and promoting the use of sustainable and recyclable plastic substitutes such as wooden cutlery instead of single-use tableware and materials Cellulose-based instead of plastic packaging and bags [85, 86].

A degrowth economy encourages the reduction in consumption habits and production with the aim of ensuring social and environmental sustainability. This is essentially needed in the usage plastic materials which in turn reduces the consumption of products in plastic materials.

Strategic degrowth, in which options are jointly decided on which market segments should dominate and which sectors should shrink. A very good example of how the Germany legitimized the transition by shutting down fossil and nuclear energy infrastructure while opening markets for new democratically-based business models to accelerate the transition. The aim is to create a market economy based on social and environmental principles, respecting the limits of the planet. a market structure that sets clear and strict limits on consumption while addressing pressing societal needs. The only problem is that a dominant obsession with economic growth can lead to one-dimensional thinking in politics, finance, economics and education that must first be measured in terms of money to appear worth preserving [87].

The circular economy in the plastics industry is a precursor to a degrowth economy because the clear interpretation of the aphorism "business as usual" of the famous $I = PAT$ formula cannot promote sustainable development. Although a degrowth economy requires radical adjustments in lifestyles and production processes, embracing it has obvious consequences for people. Beyond the ecological aspect of sustainable development, a degrowth economy also includes the social aspect. Degrowth is the process of changing societies to ensure environmental protection and a good life for all while respecting the limits of the planet. This process leads to a stable state economy, which is an economic structure that allows qualitative development, but not accumulation growth. It is a strong and sustainable economy that operates in a constant state.

I = impact of human behavior on ecosystems;

P = population (i.e., population size);

A = affluence (i.e., per capita consumption as a measure of prosperity);

T = technology (i.e., the technology needed to produce consumer goods and services, political, social and economic environment in which they are produced) [88].

5. MATERIALS AND METHODS

Comparative studies that examine different aspects of the reporting they provide are becoming increasingly popular as new multidisciplinary scholarly bibliographic data sources emerge. Scientific databases are playing an increasingly important role in the academic environment. This is due to several factors, including growing research competition and increased data accessibility [89, 90]. This is the reason for our systematic search for scientific literature from databases such as Scopus and Web of Science; justifications and the limitations are briefly discussed below. In 2004, Elsevier established the scholarly bibliographic database Scopus [30]. It is used for scientometric research [91]. Scopus is one of the largest databases of abstracts and citations for peer-reviewed literature. It offers an in-depth analysis of research results across various disciplines, including social sciences, technology, and natural sciences. The Web of Science platform provides a thorough citation search, which includes regional citation indices, patent data, subject indices, and an index of search records.

Regarding scientific literature, Science Direct is the most important Elsevier portal. It contains peer-reviewed articles from over 3,800 journals and more than 35,000 books [53]. To ensure the accuracy and transparency of the technique, the systematic literature search (Figure 4) was carried out in five steps. Generally, bibliometric study is carried out as shown in Figure 5, however, a specified bibliometric study for this study is enumerated in Figure 6.

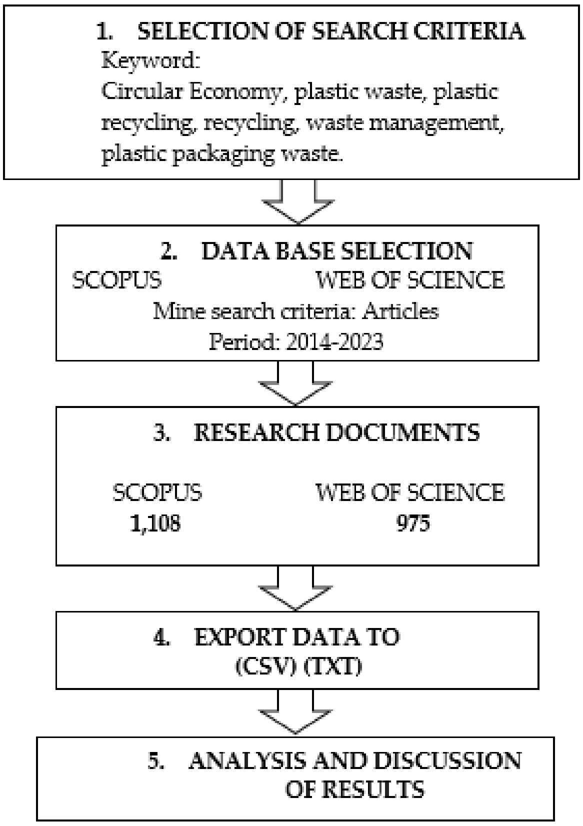

Figure 4. Flowchart of the methodology applied

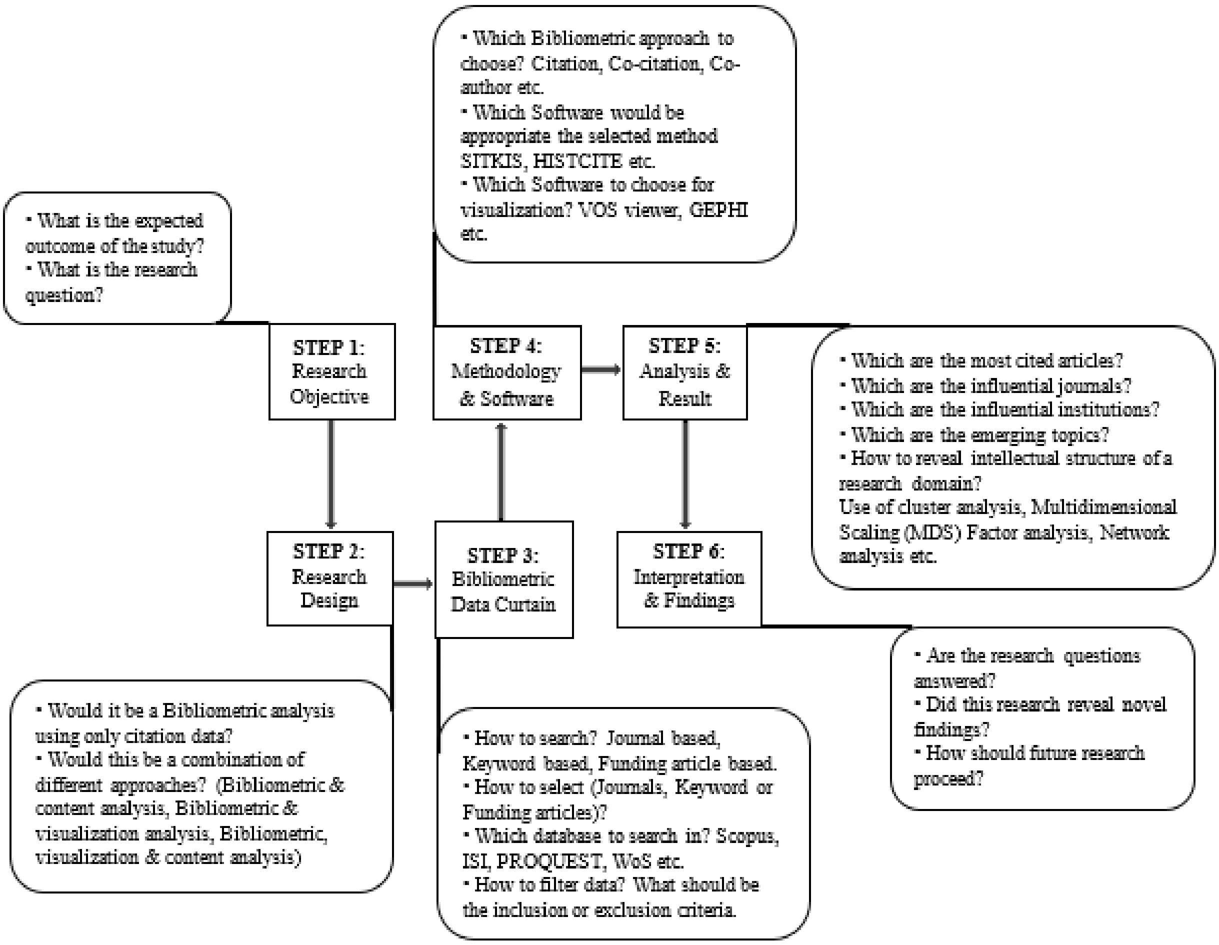

Figure 5. Generalized bibliometric analysis and citation-mapping process

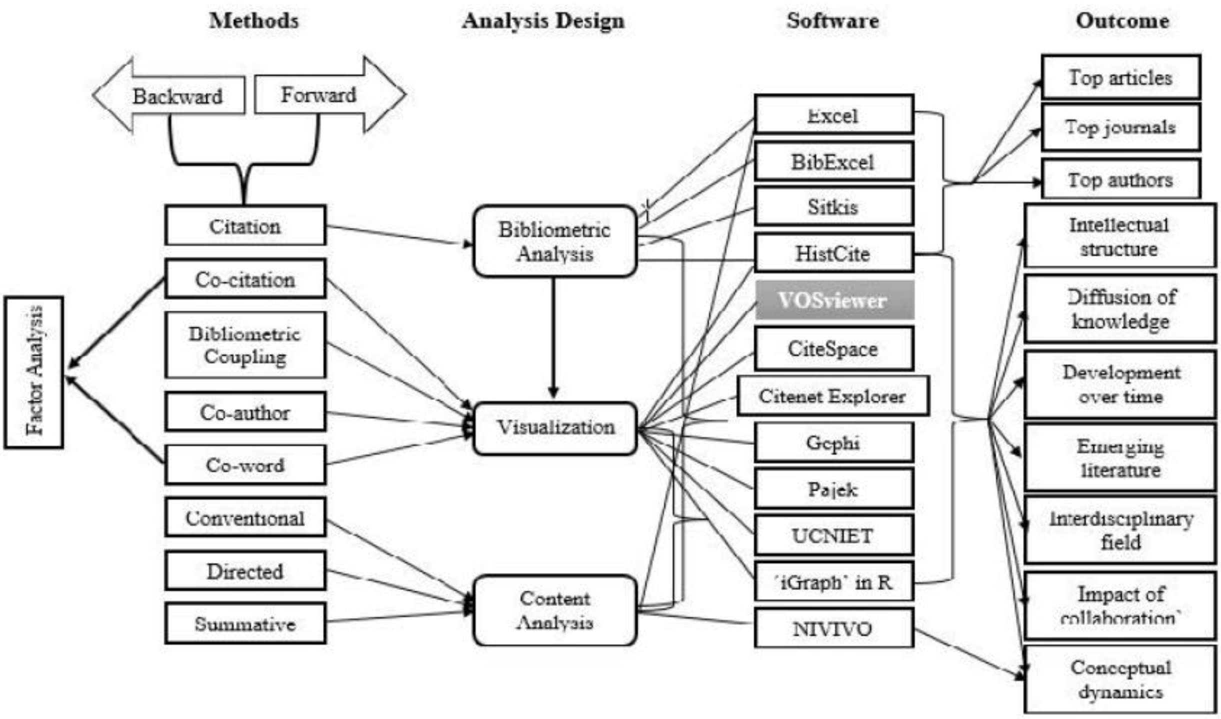

Figure 6. Specified bibliometric analysis and mapping process

The application of bibliometric analysis spans through all spheres of studies. It provides clues and ways forward to an identified problem that requires experts' solutions. The generalized bibliometric analysis addresses a research problem encompassing, the research objectives, research method design, data curtain, specified software application, analysis of results, ant the interpretation of results. One of the problems is the problem of plastic pollution and possible solutions using the circular economy approach. Conducting a bibliometric analysis of the body of knowledge on solid waste management (SWM) at the international level is one technique to achieve this goal [92-94]. To quantify these patterns and distributions, bibliometric analysis is a very useful tool [95, 96]. Bibliometric techniques have been previously applied to identify the most cited researchers [97, 98] the most mentioned keywords, and the sources from where the documents that best described CE and sustainability concepts were published [91, 99] as illustrated in Figure 7.

The purpose of this study is to establish the scope of publications based on co-authorship patterns and co-occurrence of authors. Identifying co-author collaborations and annual publications by country trends in the area of PW management.

A systematic search and review of the literature was conducted to understand the scope of author trends in the field of PW recycling research. Based on our literature search, the research tries to answer the question, "what are the authorship trends and publication volumes by countries in the plastic waste recycling" and our specific research questions are taken into account:

1. What are the annual and cumulative numbers of research documents on PW recycling?
2. Who are the most productive authors on PW recycling?
3. What are the most productive journals on PW recycling?
4. What are the most productive countries in PW recycling?
5. How does the co-occurrence of authors keywords relate?
6. What are co-authorship collaborations on PW recycling?

In order to achieve these research questions, we identify relevant studies published articles between March 25, 2023 and April 12, 2023, to describe the most recent trends of PW recycling and identified studies were imported into VOSviewer. Extracted data were tabulated using Microsoft Excel and OriginPro and the following bibliometric data drawn: coupling, co-occurrence of authors, co-authorship, and the number of times the publication was cited.

Lastly, collation, summary, and report the results give us insight on the authorship trends and publications by countries of PW recycling based on the selected databases.

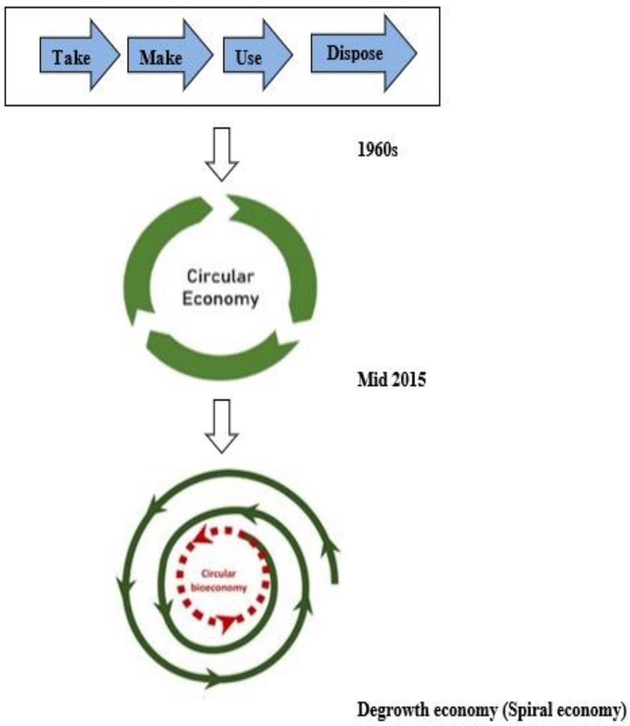

Figure 7. Three stages of the economy

5.1 Data source and search technique

To obtain the data inputs, a bibliographic data collection was carried out using Scopus on April 12, 2023, the search keywords string used: TITLE-ABS-KEY: (circular AND economy) AND (plastic AND waste AND recycling) AND (LANGUAGE, “English”). A total of 1,108 documents were discovered. The publication dates, from oldest to newest, the latest which is from 2014 is from 2023. Articles, reviews, conference papers, book chapters and other document types were considered for the study. Among other databases, the Scopus database was chosen because it offers publications with the highest scientific rigor compared to other databases [100].

A total of 975 documents from Web of Science Core Collection produced (circular economy) AND (plastic waste recycling) (All Fields) and English (Languages) for the time span of 2014 – 2023.

5.2 The bibliometric maps

The generated scopus.bib files and BibTeX files containing the data were downloaded from Scopus and the WoS databases respectively, then, the bibliometric mapping and analysis were performed using the software applications VOSviewer version 1.6.18 determining the h-index values for all documents considered for analysis. The BibTeX tool is used to format bibliographies with it, it is possible to embed BibTeX bibliographies in Word documents, although, as the name suggests, it was designed for use in conjunction with the LaTeX typesetting system.

The VOSviewer is used to view and explore maps created using network data. It is possible to highlight many elements of the literature, including institution (affiliation), co-authors, nations, citations, and keywords on the normalized term co-occurrence matrix, a measure of similarity that determines the intensity of the relationship between terms, and a combined approach for mapping and clustering [101].

6. RESULTS AND DISCUSSIONS

The choice of database fell on the scientific databases Scopus, and Web of Science. A screening was conducted using selection criteria to identify the academic papers that best address sustainable environmental development to identify the most relevant publications on this research topic. The following criteria were defined: studies from 2014 to 2023; documents, reviews and articles; journals; publications in English; and articles in the fields of circular economy, plastic industry and plastic waste recycling. After applying these selection criteria, a total of 2,083 documents from the two research databases were retrieve, 1,108 documents and 975 documents from Scopus and Web of science respectively. Data collected between the period from 25 March to 12 April 2023 are interpreted in Table 2.

Table 2. Data collected from selected databases

Database	Documents Retrieved
Scopus	1,108 documents
Web of Science	975 documents
Total documents retrieved	**2,083 documents**

The differences in the number of research documents retrieved by Scopus and Web of Science can have several possible causes and effects depending on the context in which they occur, including: coverage and content, release schedules, types of documents, citations and references, database updates and quality control, search algorithms, etc.

The final samples were managed by the VOSviewer software, which allowed the data from the selected items to be extracted and imputed into an Excel database for further analysis. Bibliometric mappings were created and compared for databases using the network visualization mode and the co-occurrence of author keywords as presented in Figures 8 and 9 for the Scopus and WoS. The Scopus data was able to generate a bibliometric coupling map with a network visualization shown in Figure 10. Also, network visualization mode based on the on co-authorships were presented in Figures 11 and 12.

Figure 10 illustrates the bibliometric coupling of all 722 documents connected to each other with the largest set of connected items consisting of 603 documents.

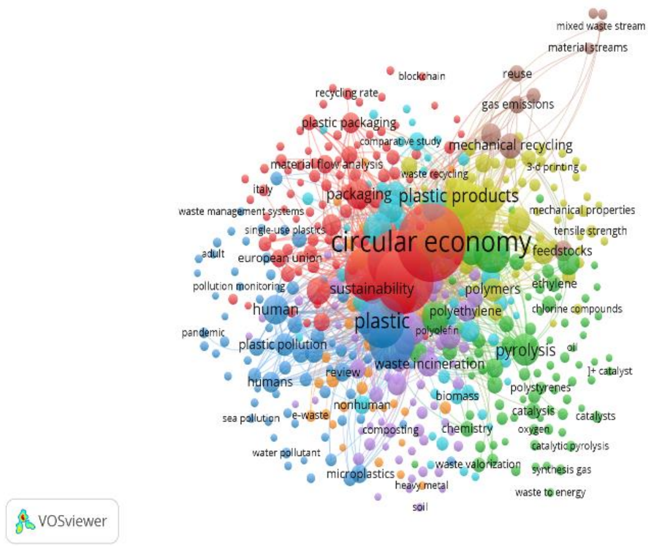

Figure 8. A bibliometric map created using the network visualization mode and the co-occurrence of author keywords. A keyword must appear at least five times: Scopus

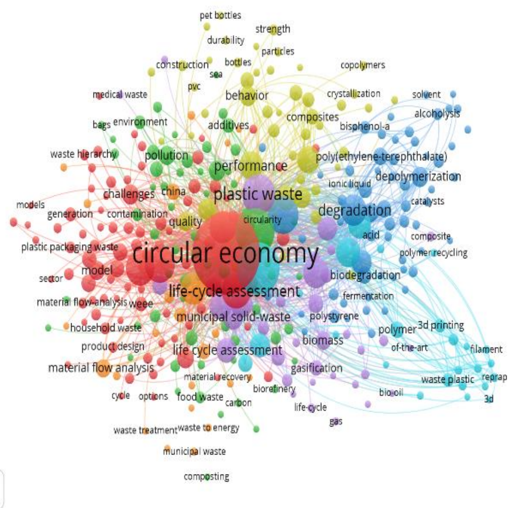

Figure 9. A bibliometric map created using the network visualization mode and the co-occurrence of author keyword. A keyword must appear at least five times: WoS

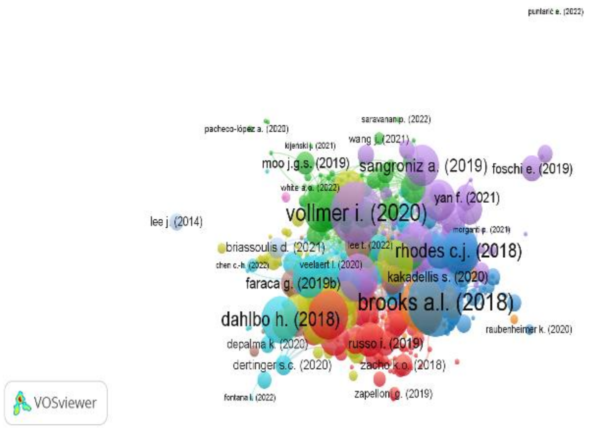

Figure 10. A bibliometric coupling created with network visualization: Scopus

It will be interesting to highlight the possible top journals and some high rank authors that has contributed to these field of studies. Table 3 present list of top most journals which are most cited in the field of CE and PW recycling research in the Scopus. Also, highlights of top most influential authors with the highest cited articles in the field of CE and PW recycling research in the Scopus are shown in Table 4. The list of top journals cited in the field of CE and PW recycling of WoS database are correspondingly highlighted in Table 5 with top most influential authors with the highest cited articles in the field of CE and PW recycling research in WoS presented in Table 6.

Identifying top journals and authors using VOSviewer requires a number of steps including: data collection and preparation, network construction, analysis in VOSviewer, cluster detection, identification of top journals and authors, visualization, and interpretation and validation.

The annual publications recorded so far within the span of study in both databases are presented and compared in Figure 13, showing higher publications are recorded in the Scopus database, while WoS records appreciable volume of publications.

Lastly, publications by countries are presented in Figures 14 and 15. Figures present countries that made at least 20 publications and more within the years of study. On both databases, the USA and the UK made the first two high ranked countries with most publications.

Differences in publication volume between countries can be influenced by a variety of factors, including historical, economic, social, and academic conditions. When examining why certain countries have higher publication rates in a given area, it is important to consider various hypotheses and factors that contribute to this phenomenon such as research funding, academic infrastructure, government policies, cultural attitudes towards education, international collaborations, language and accessibility, economic development, societal challenges, etc.

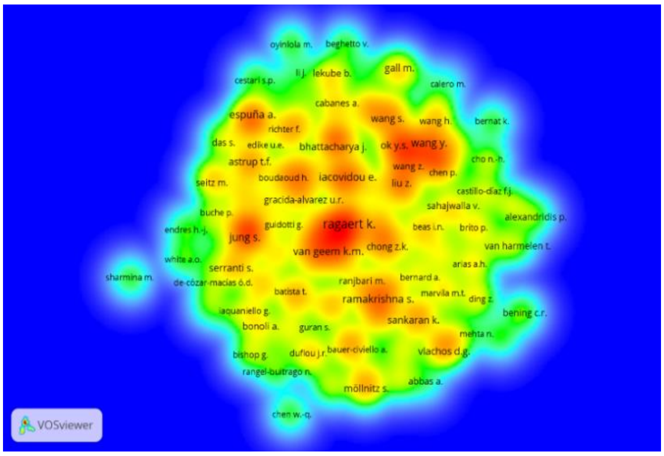

Figure 11. A bibliometric map created based on co-authorships with density visualization: Scopus (50-2-494-No)

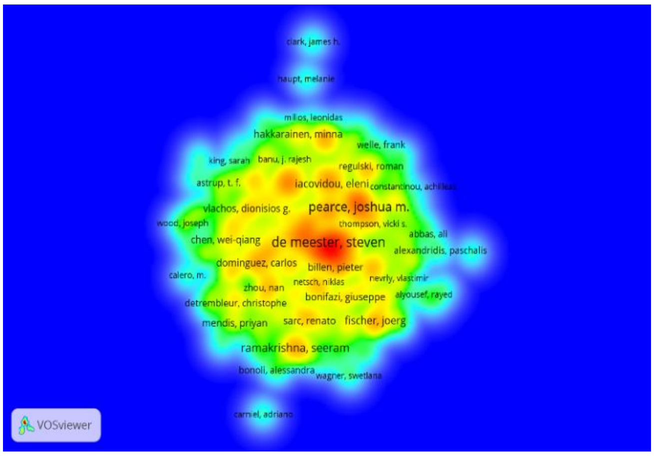

Figure 12. A bibliometric map created based on co-authorships with density visualization: WoS (50-2-494-No)

Table 3. The list of 12 top journals with the most cited articles in the field of CE and PW recycling research

Journal Name	TP	TC	Cite Score 2021	The Most Cited Article	Times Cited	Publisher
Journal of Cleaner Production	1,085	284,941	15.8	A review of conventional and novel materials towards heavy metal absorption in waste water treatment application	331	Elsevier Ltd
Resources, Conservation & Recycling	657	34,543	17.9	A critical review of the impacts of COVID-19 on the global economy and ecosystems and opportunities for circular economy strategies	105	Elsevier B.V
Sustainability	14,054	181,699	5.0	Plant growth promoting rhizobacteria (Pgpr) as green bionoculants: Recent developments, constraints, and prospects	196	MDPI
Waste Management	618	32,935	13.5	Global E-waste management: Can WEEE make a difference? A review of e-waste trends, legislation, contemporary issues and future challenges	16	Elsevier B.V
Polymers	4,449	62,327	5.7	A comparative review of natural synthetic biopolymer	205	MDPI AG

				composite scaffolds		
Science of the Total Environment	7,544	346,532	14.1	Thyroid disrupting effects of low-dose dibenzothiophere and cadmium in single or concurrent exposure: New evidence from translational Zebrafish model	899	Elsevier B.V
Waste Management & Research	158	3,109	5.9	A sustainable medical waste collection and transportation model for pandemics	39	SAGE Publications Ltd
ACS Sustainable Chemistry & Engineering	1,681	106,570	14.5	$AgFeO_2$ Nanoparticle/$ZnIn_2S_4$ Microsphere p-n Heterojunctions with Hierarchical Nanostructures for Efficient Visible -Light-Driven H2Evolution	109	American Chemical Society
Materials	7,879	95,860	4.7	Additive manufacturing processes medical applications	83	MDPI AG
Recycling	81	1,021	4.8	An overview of plastic waste generation and management in food packaging industries	81	MDPI AG
Journal Of Environmental Management	2,194	73,670	11.4	Assessing the impact of transition from nonrenewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies	197	Academic Press
Environmental Science & Pollution Research	5,357	97,758	6.6	Renewable and non-renewable energy consumption, economic complexity, CO_2 emissions, and ecological footprint in the USA: Testing the EKC hypothesis with a structural break	194	Springer

Table 4. The list of 10 top authors in the research area of CE and PW recycling: Scopus

Author's Name	Author's Scopus ID	Year of 1st Publication	TP	H-Index	TC	Current Affiliation	Country
de Meester, Steven D	50461212600	2011	102	31	2,926	Universiteit Gent Ghent	Belgium
Pearce, J.M	7402030722	2000	416	57	14,142	Western University, London	Canada
Ragaert, K	26031615400	2007	76	24	2,768	Universiteit Maastricht, Maastricht	Netherlands
Dewulf, J	7006029915	1995	371	63	15,057	Info Universiteit Gent, Ghent	Belgium
Astrup, T.F	7005097823	1999	146	50	7,401	Technical University of Denmark, Lyngby	Denmark
Faraca, G	57204172328	2019	10	8	410	European Commission Joint Research Centre, Brussels	Belgium
Fellner, J	16230143700	2004	111	30	2,639	Technische Universitat Wien, Vienna	Austria
Iacovidou, E	35573460300	2009	39	23	2,999	Brunel University of London, Uxbridge	United Kingdom
Kuchta, K	55317133200	2010	75	20	1,369	Hamburg University of Technology, Hamburg	Germany
Lang, R.W	7402129096	1997	146	159	2,481	Johannes Kepler University Linz, Linz	Austria

Table 5. The list of 12 top journals with the most cited articles in the field of CE and PW recycling research: WoS

Journal Name	TC	Citation Indicator 2021	The Most Cited Article (Reference)	Times Cited	Publisher
Resources Conservation & Recycling	68	1.63	Recycling and management practices of plastic packaging waste towards a circular economy in South Korea	39	Elsevier
Resources Conservation & Recycling	95	1.63	Towards a circular economy for plastic packaging waste- the environmental potential of chemical recycling	54	Elsevier
Composite Part C: Open Access 6	25	0	Plastics in the context of the circular economy and sustainable plastic recycling: Comprehensive review on research development, standardization and market	160	Elsevier
Waste Management	65	1.18	Plastic recycling in a circular economy, determining environmental performance through LCA matrix model approach	52	Elsevier
Science of The Total Environment 175	10	1.77	Plastic waste management: A road map to achieve circular economy and recent innovation in pyrolysis	175	Elsevier
Journal of Cleaner Production	39	1.51	Advancing circular economy benefit indicators and application on open-loop recycling of mixed and contaminated plastic waste production	24	Elsevier
Journal of Environmental Management	18	1.38	A review of the plastic value chain from a circular economy perspective	70	Elsevier
Journal of Cleaner Production	8	1.51	A circular economy framework for plastics: A semi-systematic review	128	Elsevier
Macromolecular Journals Rapid Communications	2	0.93	Closing the carbon Loop in the Circular Plastics Economy	637	Wiley
Polymers	0	0.88	Plastic waste upcycling: A sustainable solution for waste management, product development, and circular economy	112	MDPI
Resources Conservation &	35	1.63	Techno-economic assessment of mechanical recycling of	47	Elsevier

Recycling			challenging post-consumer plastic packaging waste		
Science of The Total Environment	31	1.77	Circular economy in plastic waste-Efficiency analysis of European Countries	46	Elsevier

Table 6. The list of 10 top authors in the research area of CE and PW recycling research: WoS

Author's Name	Author's WoS ID	Year of 1st Publication	TP	H-Index	TC	Current Affiliation	Country
de Meester	DUZ-1061-2022	2011	94	29	3,463	Maastricht University Ghent University Dept Green Chem and Technology	Belgium
Ragaert, Kim	FZS-1385-2022	2010	63	22	2,391	Maastricht University Ghent University HOGENT University College of Applied Science & Arts	Netherland
Dewulf Jo	GBQ-2210-2022	2002	273	53	10,745	Ghent University Swiss Federal Institutes of Technology Domain European Commission Joint Research Centre Chalmers University of Technology	Belgium
Astrup, Thomas Fruergaard	AAQ-4329-2021	1999	140	48	9699	Technical University of Denmark Denmark	Denmark
Pearce, Joshua M.	DVC-	2014	101	18	901	Western University (University of Western Ontario) 1151 Richmond St N Alliance Feed Earth Disasters ALLFED Aalto University Michigan Technological University Universite de Lorraine Queens University	Canada
Van Geem, Kevin M	EAK-019-2022	2019	141	18	1388	Ghent University	Belgium
Kuchta, Kerstin	FFS-1529-2022	2004	67	18	1169	Hamburg University Technology Hamburg Univ Technol Sustainable Resource & Water IUE Tech Univ Hamburg Hochschule Angewande Wissenschaft Hamburg	Germany
Sarc, Renato	AAL-6075-2020	2012	32	12	552	University of Leoben Univ Montana	Austria
White,Alvin Orbaek	DWX-7343-2022	2010	33	14	633	Swansea University Swansea Univ Bay Campus Massachusetts Institute of Technology (MIT) Rice University	Wales
Vilches, Berdugo	Teresa	DXB-7294-2022	2018	20	10	Chalmers University Sweden Technology	Sweden

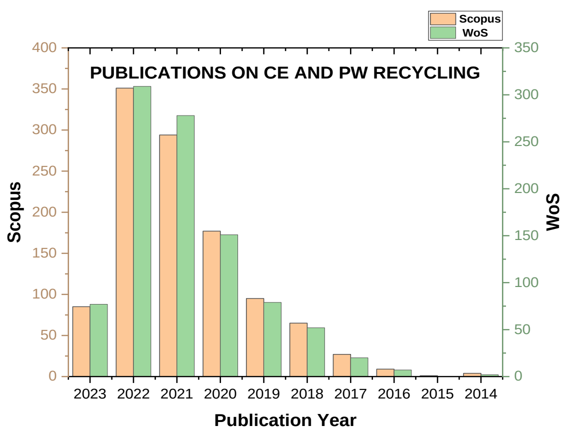

Figure 13. Annual and cumulative numbers of research documents on CE and PW recycling in Scopus and WoS from 2014 until 2023

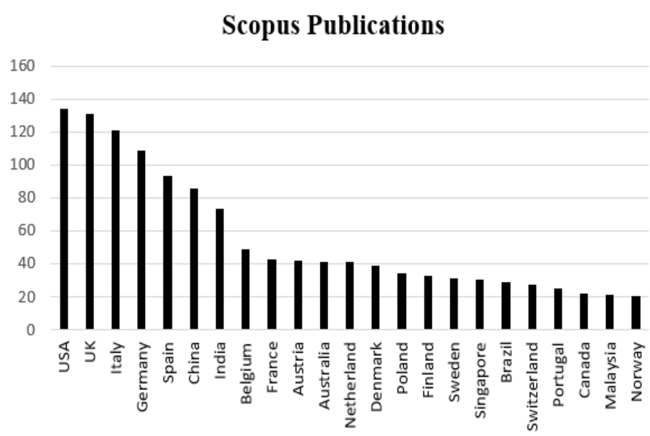

Figure 14. Scopus publications by country on CE and PW recycling

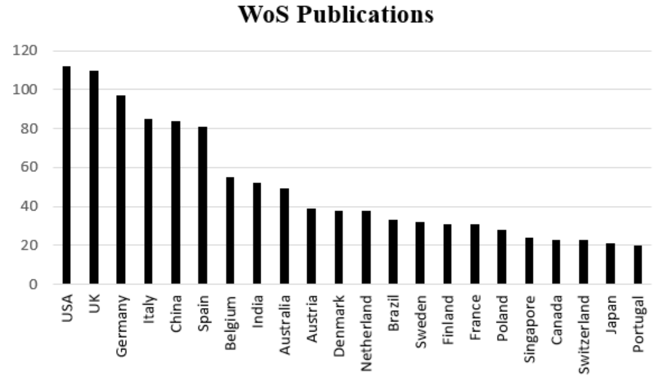

Figure 15. Web of Science publications by country on CE and PW recycling

7. CONCLUSION

The volume of publications included in the two bibliometric databases allows us to highlight the importance of the circular economy as a topic of study. Their importance can be explained by comparing the results with those of other bibliometric analyses. Similar and more recent research has shown that between 2014 and 2023, plastic waste produced 1,108 and 975 articles on Scopus and the Web of Science; These numbers significantly represent the records published about this study [102].

This study used the two most popular literature databases, Scopus, and Web of Science, to perform a bibliometric analysis of the worldwide scientific literature on CE and PW recycling. Using these comparative studies, it was possible to identify patterns and trends in CE research while highlighting global similarities and differences. The conclusions and suggestions below are based on the results.

Although the concept of the circular economy was first introduced in late 2015, its main objective is to ensure that as we create economic growth, new jobs, and growth, we continue to protect the environment. To this end, the European Union has adopted a comprehensive circular economy package that includes targets for recycling plastic, food and water [46]. This article provides an up-to-date analysis of the circular economy by highlighting the key authors, publications and outcomes of conceptual structures associated with the circular economy.

This concept is supported by facts that the most relevant work on the topic is currently tied to ideas in waste management, that the most prominent authors also have ties to plastic waste, and that the management and recycling are linked to alternative metrics. It is also important to note that several articles are indexed in the thematic categorization of WoS and Scopus publications in the field of general waste and plastic waste management. The circular economy is now applied in more areas, which is the second development. If we examine the strategic diagrams, we can see this trend towards decentralization with the introduction of new areas of interest that are not only focused on the original meanings of the circular economy [103].

The first three authors who have published the most articles on the circular economy are: de Meester, Steven D (102 TP), Pearce, J.M (415 TP), Ragaert, Kim (76 TP) on the Scopus database, while de Meester, Steven D (94 TP), Ragaert, Kim (63 TP), and Dewulf, Jo (273 TP) are the first three authors with the most published articles on the Web of Science database. Both databases have in record that the most published articles are from de Meester, Steven D with total of 102 and 94 publications on the Scopus and the Web of Science databases. The first authors on both databases are from Belgium, followed by one Canada, Netherlands and Netherlands, Belgium. As a result, there is still a tendency to approach the circular economy from an environmental perspective, considering how industrial activities are impacting the environment.

A broader perspective on the bibliometric impact of the circular economy is provided over time as per the definition of the scope of the study [101]. This research supports previous bibliometric analyses. The analysis performed in this study is statistically more thorough and comprehensive in terms of the databases used to obtain the data used. The three most relevant journals on the study area [104], Journal of Cleaner Production and Resources, Conservation and Sustainability, were found by analyzing the development of the main articles.

Considering the Scopus database, the keywords in the research clusters included circular economy (CE), recycling, plastic recycling, waste management, plastic waste, plastics. Similarly, the research clusters in the Web of Science database consisted of Recycling, plastic packaging waste, circular economy (CE), plastic recycling, plastic waste management. These similarities in circular economy (CE) and plastic waste (PW) research indicate differences in research priorities and skills. This shows that more resources should be allocated to the development of municipal waste management research (MSWM) in the developing countries so that it can keep up with international trends, especially when compared to developed countries. Therefore, stronger research prioritization in African developing countries is recommended for the following research topics:

- Contribution of PW in achieving sustainable development goals;
- Life cycle assessment of PW;
- Formulating suitable PW recycling strategies;
- Landfill location, GIS and computer modelling;
- Impacts of COVID-19 on PW generation;
- Contribution of PW in the CE.

Based on the input from the analyzed databases, eco-friendly solutions listed below should be developed and implemented to shorten the plastic product lifetime and thus reduce the generation of waste. This is achievable by policymakers encouraging businesses and consumers to recycle more plastic waste through rewards, benefits, taxes and policy interventions that support innovation and promote a circular economy [105].

- Awareness, Education, and Information
- Infrastructure and Public procurement
- Legal framework
- Platforms for collaboration and innovation support
- Taxes plans
- Framework for regulation

The circular economy agenda is changing the paradigm of plastic waste management in the community. Through the publication of various rules and procedures, the transition to circularity has been implemented in several countries around the world. In many countries, low recycling rates are a significant barrier because it is expensive and has few facilities [106].

However, the limitations of this study are simultaneous transformation of these co-developed systems to the degrowth system to maintain well plastic waste recycling structures, which will pose a problem. How best to organize this and the potential impact this transformation can have on well-being is not yet fully understood [107].

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