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Barriers to Integrating the Circular Economic Model Into the Municipal Solid Waste Management System: Systematic Review

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ABSTRACT

The circular economy is considered a key tool for sustainable development, capable of transforming the traditional economic model, operating it as a closed-loop system, and utilizing "waste" as a resource for the production of new products. The research results systematically discuss the theory, including the problems and obstacles to the integration of the circular economy model into the municipal solid waste management system. It structures the problems and obstacles found in the literature from a dual perspective that complicate, hinder, or even delay the integration. The study did so by reviewing 116 scientific articles from five perspectives–economic, social, environmental, technological, and policy–considering the stages of effective municipal solid waste management: waste generation; collection, sorting; reuse, recycling, recovery from waste; final waste disposal. The systematic review showed that, in addition to numerous economic, social, and environmental obstacles to the integration of the circular economy, technological and political obstacles must also be taken into account. However, to overcome all of these, an effective waste management system must first be operated in each country. To do this, for each stage of municipal solid waste management, the problems and obstacles identified in the study for the given country should first be overcome and resolved.
Keywords: circular economy, municipal solid waste management, barriers, global, systematic review

1. INTRODUCTION AND LITERATURE REVIEW

In 2020, 2.24 billion tonnes of solid waste were generated in the world, i.e., an average of 0.79 kg of waste was produced per day by an inhabitant of the Earth (Chen et al., 2023; Jayasinghe et al., 2023), which has decreased to 2.1 billion tons according to the latest data (United Nations, 2024b). This figure is predicted to increase by 70 % by 2050 (World Bank, 2018) and reach 3.8 billion tonnes, which represents an exponential increase in waste production (Etim, 2024) unless we act urgently.

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Inadequate waste management (WM) is a growing global problem with serious economic, environmental, and social consequences (environmental damage, public health hazards) that we have to face. Municipal solid waste management (MSWM) is a critical activity worldwide in terms of sustainability, but it faces challenges in waste generation, collection, treatment, and disposal.
Recognizing the significant challenges posed by inadequate WM, international organizations are increasingly advocating for immediate, comprehensive waste management measures (Abe & Didham, 2013). However, this requires coordinated efforts by communities at all levels (United Nations, 2024a; Lama, 2024).
The European Commission (2023) also emphasized that national authorities must step up their political efforts and accelerate national action, as even the member states of the European Union (EU) are still far from their 2025 goals. The basis of the EU's WM and policy, as well as its legislation, is the waste hierarchy, as documented in the EU framework directive on waste (Directive 2008/98/EC). One of the main goals of this is to minimize the harmful effects of waste generation and treatment, while the other is to improve the efficiency of resources.
In the literature, the concept of the circular economy (CE) is widely debated. The model now carries its ecological principles, as it was closely linked to reuse and recycling (Kirchherr et al, 2023). The concept of the CE changes the traditional "take-make-waste" management model. This approach envisages a restorative and regenerative approach to economic activities and industrial processes. The aim of the model is to try to keep resources, materials and products in circulation for as long as possible using a system-oriented approach; therefore, durability, repairability and longevity are prioritized during the design of products and systems (Bakker et al., 2021; Tukker, 2015). If the given product reaches the end of its life cycle, the component materials are returned to the production cycle, reducing the amount of waste and minimizing the need for new raw materials, i.e., reuse prevents them from becoming waste (Den Hollander et al., 2017; Morseletto, 2020; Zink & Geyer, 2017). The aim of the concept is therefore to recover waste as a resource for the production of new products and values at the end of their life cycle, thereby closing the loop in the cycle (Di Maio & Rem, 2015; Popović & Radivojević, 2022). CE emphasizes resource efficiency at every stage of the product's life cycle, whether through effective design, minimizing resource waste in production, or responsible consumption (Geisendorf & Pietrulla, 2018; Hapuwatte & Jawahir, 2021; Mestre & Cooper, 2017). CE, when designed thoughtfully and inclusively, can sustainably protect the environment, strengthen the economy, and advance social justice (EPA, 2024).
The CE system diagram, also known as the butterfly diagram, illustrates the continuous flow of materials in CE, which has two main cycles. In the technical cycle, products and materials are kept in flow and circulation through processes, such as repair and remanufacturing, reuse, and recycling. During the biological cycle, nutrients from biodegradable materials are returned to nature to regenerate it (Ellen MacArthur Foundation, 2021).
Knowing all this, it can be said that the application of the CE approach has many economic (increasing employment, job creation, economic growth, promoting innovation) (Horbach et al., 2015; Mhatre et al., 2021; Schroeder et al., 2019; Suchek et al., 2021), social (minimizing inequalities, promoting well-being, encouraging cooperation) (Mies and Gold, 2021; Schröder et al., 2020; Velenturf & Purnell, 2021) and environmental (reducing pollution levels, resource load) (Quina et al., 2018; Xavier et al., 2021) advantages.
However, many cultural, social, and environmental barriers of CE have also been identified. One such cultural barrier is the hesitant corporate culture (Kirchherr et al., 2017). Challenges related to quality and availability appear as social constraints for secondary materials (Hsu et al., 2022).

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Regarding the environmental aspect, there is a lack of information on the benefits of circular systems for the natural environment (Harris et al., 2021).
Based on the above ideas, the following research question was formulated: What are the problems and barriers of integrating the CE model into MSWM? A systematic literature review method will be used to answer this question. Nowadays, specialized literature databases have grown significantly across most scientific fields, making it hard to keep up with the latest research results. Systematic literature analysis has become an increasingly widespread method and a key tool for scientific research (Kartali, 2023).
The result of this research systematically discusses the theory, including the problems and barriers to integrating the CE model into the MSWM system. From a dual point of view, it structures the problems and barriers found in the literature that make it difficult, hinder, or even delay the integration of the circular economic model into MSWM. By summarizing the results, findings, and possible recommendations, the aim of the study is to help integrate the concept and practice of CE into MSWM. The study can also function as a forward-looking analysis that identifies past and present shortcomings and tries to make recommendations that can lay the foundation for future research and development of sustainable concrete practices on the subject.

2. MATERIALS AND METHODS

A systematic literature review (SLR) is defined by Fink (2014) as a method that uses a structured and documented procedure to review, evaluate, and synthesize the available scientific literature for a specific research question or topic. According to Denyer and Tranfield (2009), a systematic review is a specific methodology that, in itself, is an independent research project and explores a clearly defined question, usually arising from a practical problem, with the help of existing studies. The SLR uses a scientific methodology that collects and analyzes all existing research results related to a specific question, and then seeks to answer professional questions by evaluating them through well-defined steps (Kamarási & Mogyorósy, 2015). The method, therefore, identifies, selects, and critically evaluates research in order to answer a clearly formulated question (Dewey & Drahota, 2016).
SLR can moderate the influence of heuristics (Spector & Thompson, 1991; Tranfield et al., 2003), thereby more specifically revealing and explaining the current position of science regarding the examined issue and problem (Rousseau et al., 2008). Traditional literature methods are often criticized for being highly subjective (Petticrew & Roberts, 2006); however, the search, selection, and processing frameworks set by this method ensure a certain level of objectivity and reproducibility (Gough & Thomas, 2012). SLR also plays an important role in the development of Supply Chain Management (SCM) knowledge (Moraes et al., 2020).
During the literature review, the author of the study searched five academic research databases– Science Direct, SpringerLink, Wiley Online Library, Web of Science, and JSTOR Journals–for scientific journal articles in English. A special search was conducted for the period between January 2010 and October 2024 using the keywords “municipal solid waste management” OR “MSWM” AND “circular economy” that were found in the abstract or title.
Applying the special filters, the keywords were found in a total of 1100 articles in the listed databases. These scientific works provided the basic set for narrowing down the publications to be processed in the study. After that, the author of the study filtered out the duplicates, leaving only documents with open and free access in the set of scientific journal articles, resulting in 516 articles. A further narrowing down was done based on the scientific classification of the articles

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(environmental, social, business and management, and sustainable science), title, and content of the abstract. Based on these, the author of the study selected 202 studies for full reading. After fully familiarizing with the studies, the author selected articles relevant to answering the research question, based on which the author could obtain an answer to the research question. Finally, the study reduced the set to a total of 116 relevant articles from which the problems and barriers to the integration of the CE model into MSWM could be identified and used for further analysis and grouping of the identified factors. The results of the four-round search process are shown in *Table 1*.

Table 1: Results of a four-round search process and narrowing down

Databases	Number of filter results			
	Round 1: Based on a search with keywords in the title, keywords, abstract	**Round 2: Duplication with filtering, based on open access/free**	**Round 3: Academic field classification based on abstract content**	**Round 4: Based on reading the full announcement**
JSTOR Journals	117	10	3	1
Science Direct	119	31	21	15
SpingerLink	39	8	6	4
Web of Science	817	464	169	96
Wiley Online Library	8	3	3	0
TOTAL	1100	516	202	116

The PRISMA flow diagram *(Figure 1)* depicts the flow of information through the different phases of a systematic review. It maps out the number of records identified, included and excluded, and the reasons for exclusions.

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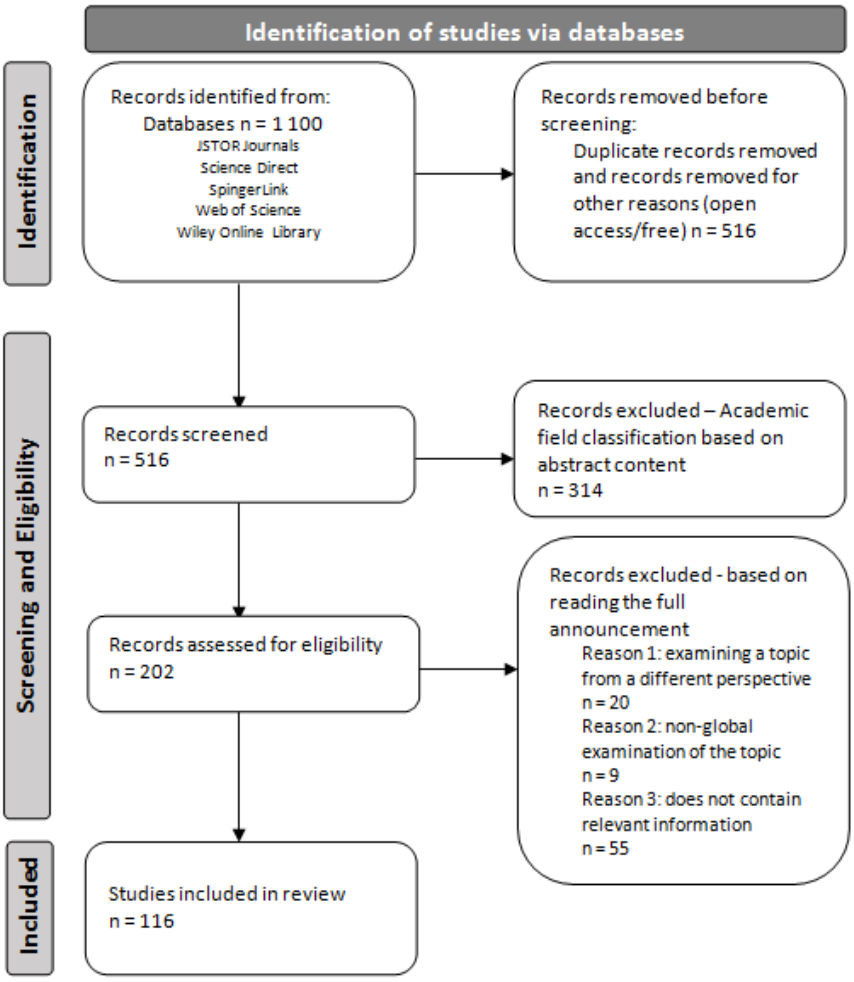

Figure 1: PRISMA flow diagram

As shown in *Figure 2*, most studies in the mentioned topics were published in 2020. It is worth highlighting that journals in other subjects (e.g., earth, law, geography, engineering, energy, economics, ecology, materials science, etc.) also deal with the research topic. This can be beneficial in terms of a holistic and broad presentation of research results. Due to the multidisciplinarity of the chosen research topic, it is advisable to process the results of several scientific fields when preparing the systematic literature review, when grouping and presenting the results.

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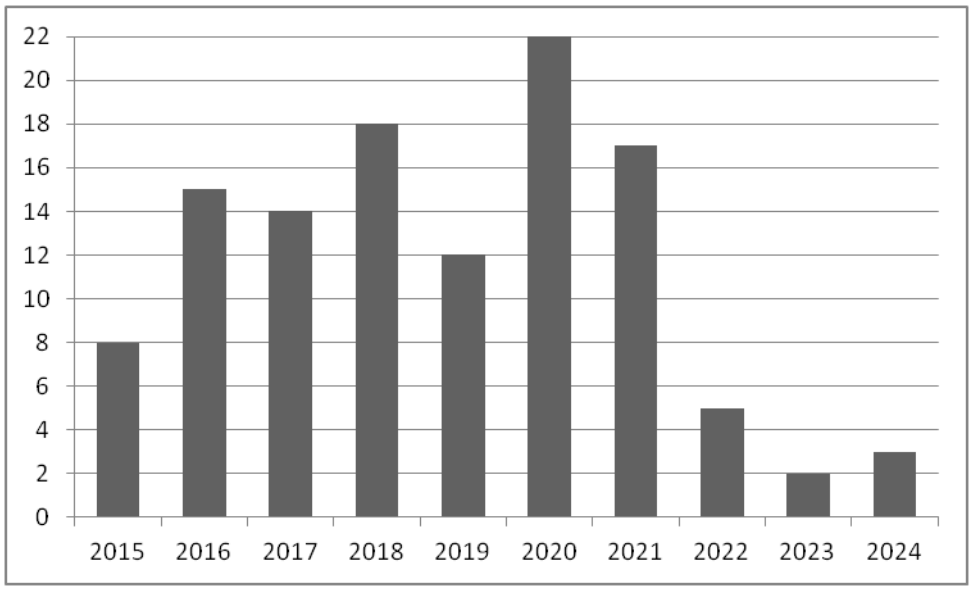

Figure 2: Distribution of the publication years of selected studies

3. RESULTS

After processing the articles, based on the qualitative content analysis of the selected 116 studies, the study organized the results based on three main aspects, in line with the basic framework of the CE that addresses three central pillars: economic development (economic aspects), social upliftment (social aspects), and a healthy environment (environmental aspects). However, based on the systematic review, the author of the study believed that it was appropriate to examine the topic from two additional perspectives – political and technological – (*Table 2*); therefore, these aspects were also added to the systematization.

Effective solid waste management (SWM) includes several stages: *(1)* collection and sorting of waste, (2) reuse and recycling of waste, (3) recovery from waste, (4) final disposal of waste. Each stage has its own significance in the efficiency of the MSWM system (Sondh et al., 2024), so the author of the study investigated the research question according to the stages. However, as a starting point, the author of the study thought that the generation of municipal solid waste (MSW) should also be dealt with, since the amount, quality, and nature of the generated waste determine the entire process of waste management. Of the identified stages of effective solid waste management, the stages of waste reuse and recycling, and the stage of recovery from waste were combined to categorize the results because these stages result in the usability of secondary products derived from waste.

Table 2 summarizes the problems and obstacles to integrating the CE model into the municipal solid waste management system from economic, social, environmental, technological, and political perspectives. The results show that the problems and obstacles related to municipal solid waste generation are presented in the literature primarily from an economic and political perspective. Technological and social obstacles are typical during waste collection and sorting. Problems related to the reuse, recycling, and utilization of waste are largely social, technological, and political in nature. In the case of final waste disposal, environmental and technological problems and obstacles come to the fore.

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Table 2: Problems and barriers of the integration of CE model into MSWM system from an economic, social, environmental, technical political point of view

Framework of CE	
0. Generation	
Economic aspects	different economic situations of countries; complexity of waste management system; increase in production; other priorities competing for resources; lack of understanding of factors affecting waste management system; increasing burden on local government budgets
Social aspects	different social structures; resource waste; food waste; lack of awareness
Environmental aspects	resource constraints; resource waste; exponential growth of waste; waste varies in quantity, nature, quality, and composition by country, region, and space
Technological aspects	no information
Political aspects	increasing burden on local governments
1. Collection – sorting	
Economic aspects	complex task; lack of financial resources; disorganization; lack of responsible production; high operating and maintenance costs; lack of multilateral partnerships with other sectors
Social aspects	lack of knowledge about waste; lack of awareness to segregate waste; lack of public participation; insufficient and remoteness of recycling containers; length of collection time; lack of responsible consumption; lack of stakeholder cooperation, social inequalities; lack of integration of informal sector into MSWM system
Environmental aspects	lack of knowledge; low environmental awareness; waste heterogeneity; MSW is complex, complicated; dependence on primary raw materials; waste does not enter the recycling stream
Technological aspects	different SWCs; different logistics and operational activities; insufficient infrastructure; time constraints; poor collection route planning; lack of information on collection schedules; insufficient number and capacity of collection vehicles; lack of waste separation systems; insufficient number and spacing of separate waste collection containers; incorrect collection practices and transportation of waste fractions and bins; lack of segregation according to the source of waste generation
Political aspects	disorganization; limited ability of government to meet demand for MSWM services; lack of multilateral partnerships with other sectors; ineffective implementation of waste management policies; lack of state capacity to manage waste to the required extent
2. Treatment: reuse, recycling, recovery	
Economic aspects	complex, complicated capital-intensive task; lack of financial resources; high waste management costs, inefficient waste management protocol; lack of market demand for secondary raw materials; lack of financial strategies ensuring the financial viability of waste service providers; emerging supply chains;
Social aspects	scepticism about WtE or W2E; social inequalities; low awareness; NIMBY; lack of social recognition; social discrimination; lack of public awareness, stakeholder involvement; lack of communication of risk factors; poor public awareness; local community resistance to waste management; incomplete data collection and evaluation; ZWE position; value and potential of MSW not recognized; excessive consumption of primary materials
Environmental aspects	significant global footprint of SW production; different environmental conditions; other, non-environmental priorities; incomplete data collection and assessment; incomplete environmental knowledge; strict environmental regulations, legislation;
Technological aspects	WtE/W2E is not just about incineration; lack of technological knowledge; application of traditional waste management practices; lack of waste recovery systems; lack of understanding of factors affecting the waste management system; lack of adequate waste pre-treatment; maturity of technologies; implementation of waste management practices in an inadequate time and coverage; lack of waste management infrastructure; poor quality of waste management products

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Political aspects	lack of systematic national policies and legislation; implementation barriers, limited procedures for WtE/W2E technologies; limited recycling practices and policies; MSWM policy exists but is not implemented effectively; regulatory barriers to commercialization of new technologies; weak bureaucratic structures of MSWM institutions; shortcomings in MSWM governance; gap between MSWM policy and practices; limited control; ineffective policy regulatory framework
3. Disposal	
Economic aspects	lack of financial resources
Social aspects	lack of awareness; lack of skilled labor; lack of public acceptance of the establishment of landfills
Environmental aspects	"infinite" decomposition time; air pollution; water pollution; soil pollution; selection of landfill sites
Technological aspects	indiscriminate dumping, open dumping; mass, open burning; use of incorrect disposal procedures; lack of well-designed, equipped landfills; lack of technology; no recycling, utilization
Political aspects	lack of legislation

Countries face many MSWM challenges. This review emphasizes the effectiveness of the phases of the MSWM system based on the 4 Rs of CE framework–reduce, reuse, recycle, and recover–by highlighting and systematizing waste collection and sorting, reuse and recycling, extracting value from waste, and the importance of its utilization.
The analysis and evaluation of CE practices based on economic, social, and environmental aspects help monitor the development of sustainable WM. The three pillars must develop in harmony with each other for a stable and efficient WM model.
In the following, I will describe in detail the problems and barriers categorized from a dual point of view, as well as their effects and possible ways to remedy them.

4. DISCUSSION AND CONCLUSION

The circular economy is considered a key tool for sustainable development, which is capable of transforming the traditional economic model when it operates as a closed-loop system and utilizes "waste" as a resource for the production of new products.
This systematic review identified numerous problems and barriers to integrating the CE model into MSWM. The study did so by reviewing 116 scientific articles from five perspectives–economic, social, environmental, technological and policy–considering the stages of effective municipal solid waste management: waste generation; collection, sorting; reuse, recycling, recovery from waste; final waste disposal. The systematic review showed that, in addition to the numerous economic, social, and environmental barriers to the integration of the circular economy, technological and political barriers must also be considered. The literature presents the problems and obstacles related to the generation of municipal solid waste from an economic perspective. The most typical problems are: differences in countries' economic situations, increased production, and competing priorities for resources. Technological obstacles are common in waste collection and sorting; the most common are: insufficient infrastructure, time constraints, lack of waste separation systems, and lack of segregation according to the source of waste generation. Problems related to the reuse, recycling, and utilization of waste are also largely technological in nature, such as: lack of technological knowledge, lack of waste recovery systems, inadequate waste pretreatment, and inadequate timing and coverage for implementing waste management practices.

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Technological problems and obstacles also come to the fore in the case of final waste disposal, including: indiscriminate dumping and open dumping; lack of technology; and no recycling or utilization. However, to overcome all of these, an effective waste management system must first be in place in each country. To do this, for each stage of municipal solid waste management, the problems and obstacles identified in the study for the given country should first be overcome and resolved.

CE-controlled WM emphasizes environmental justice and thus provides an opportunity to effectively alleviate these problems and eliminate barriers. A CE-led waste management system has the potential to provide a structure that stabilizes and strengthens the economy, improves natural resource management, and protects individuals' human rights (Sondh et al., 2024).

Although many studies have investigated sustainable MSW approaches, there is a lack of holistic approaches to MSW monitoring and management at the global level (Das et al., 2019). However, achieving circularity requires a holistic system approach, which includes production, consumption, and WM (Bianchi & Cordella, 2023).

A sustainable production and consumption model requires businesses to change their production patterns, while at the same time focusing on involving consumers, who need economic opportunities to access affordable, sustainable products. Technological progress can facilitate the exploitation of economies of scale and experience, making sustainable development competitive. Transboundary flows of waste should be minimized and all countries should be enabled to adopt technologies that maximize reuse and recycling while minimizing unsustainable waste management practices (e.g., use of landfills) (D'Adamo et al., 2024).

However, the challenges to achieving the optimum are not only technical, but also economic, political, and cultural. Sustainability goals require finding a balance between economic profitability and sustainable consumption to meet citizens' needs (D'Adamo et al., 2024).

However, no consensus has yet been reached on the best MSW management approach, as evaluation criteria in existing studies are inconsistent. For converting MSW to energy, economic metrics, such as capital, compliance, and operating cost, are important aspects of implementation (Hoang et al., 2022). Developed countries are using WtE technologies more widely (Chen et al., 2020), as they have recognized the real potential of WtE to simultaneously solve waste and energy problems globally (Skaggs et al., 2018). The transformation of waste into useful energy can not only reduce pollutants entering the environment but also diversify the energy sources available, depending on the technological capabilities of individual nations, regions, and settlements.

However, expanding the circular economy in municipal solid waste management not only means technological development, but also a change in perspective, institutional reform, transformation of economic incentives, and social participation. The emphasis should be on a waste-to-resource approach, prevention, and the development of local cycles. From a systems perspective, municipal waste management is not "waste management", but a local resource management system that strives to close the material cycle and minimize environmental impact.

Several analyses have shown the significant ecological benefits of reusing water, energy, and materials, which reinforce the value of circular strategies for sustainability (Nikolou & Tsagarakis, 2021). However, strict policies to combat illegal waste flows can undermine CE practices (D'Amato et al., 2018).

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A körforgásos gazdaság integrációs akadályai a települési szilárdhulladék-gazdálkodásban: szisztematikus áttekintés

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ÖSSZEFOGLALÁS

A körforgásos gazdaságot a fenntartható fejlődés kulcsfontosságú eszközének tekintik, amely képes átalakítani a hagyományos gazdasági modellt, zártláncú rendszerként működtetni azt, és a „hulladékot" új termékek előállításához szükséges erőforrásként hasznosítani. A kutatási eredmények szisztematikusan tárgyalják az elméletet, beleértve a körforgásos gazdasági modell települési szilárdhulladék-gazdálkodási rendszerbe való integrációjának problémáit és akadályait is. Kettős perspektívából strukturálja a szakirodalomban található problémákat és akadályokat, amelyek bonyolítják, akadályozzák vagy akár késleltetik az integrációt. A tanulmány ezt 116 tudományos cikk öt – gazdasági, társadalmi, környezeti, technológiai és politikai – szempontból történő áttekintésével tette, figyelembe véve a hatékony települési szilárdhulladék-gazdálkodás szakaszait: hulladékkeletkezés; gyűjtés, válogatás; újrafelhasználás, újrahasznosítás, hulladékból való visszanyerés; végső hulladékártalmatlanítás. A szisztematikus áttekintés kimutatta, hogy a körforgásos gazdaság integrációjának számos gazdasági, társadalmi és környezeti akadálya mellett a technológiai és politikai akadályokat is figyelembe kell venni. Mindezek leküzdéséhez azonban először minden országban hatékony hulladékgazdálkodási rendszert kell működtetni. Ehhez a települési szilárdhulladék-gazdálkodás minden szakaszában először le kell küzdeni és megoldani az adott országra vonatkozóan a tanulmányban azonosított problémákat és akadályokat.
Kulcsszavak: körforgásos gazdaság, települési szilárdhulladék-gazdálkodás, akadályok, globális, szisztematikus áttekintés

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