Journal of Research and Innovation for Sustainable Society (JRISS)
Volume 7, Issue 2, 2025
ISSN: 2668-0416
Thoth Publishing House

DOI: 10.33727/JRISS.2025.2.9:107-126

Reaching sustainability. Exploring the development of technologies in the field of waste disposal: theoretical background and patent landscape analysis

Ventsislava Nikolova-Minkova[1]

[1]Faculty of Economics, Technical University of Gabrovo, Bulgaria
ORCID: 0000-0002-1492-2298

E-mail: minkova.ventsislava@gmail.com

Abstract. The issue of sustainable development of society has many sides, and in this study, we will consider one of them, namely the problem of generated waste. Our goal is to explore patent statistics indicating the development of technologies in the field of waste disposal, which contributes to reducing people's footprint and negative impact on the environment. To achieve the goal of the study, we use patent landscape analysis (PLA) on the classification codes B09B and B65F, through which we identify not only the trends of technological development, but also the main participants and innovators in the field of waste disposal. We also apply graphical and comparative analysis of the data extracted from The Lens Database. As a result, we found a positive trend of growth in the number of patent documents for waste disposal technologies, with the most significant contribution in this regard being the granted limited patents for utility models to holders from China. We outlined the leading patent holder countries and companies in each classification index and displayed the patent documents with the highest citation.
Keywords: *sustainability*, *innovation, technology, patent landscape analysis, waste disposal, circular economy.*

Introduction

One of the main problems accompanying the development of society from prehistoric times to the present day is the imprint that people leave on nature. From the beginning of the intellectual development of people, when there is an internal need for the association of individuals, groups, communities, and settlements are formed, human activity and life create environmental problems. With the appearance of the first civilized cities, which gradually grew, and, on whose territory, a larger number of populations was concentrated, there were prerequisites for the assimilation of larger territories of nature, the extraction of more resources and the accumulation of larger amounts of waste. At a later stage, in parallel with the development of the Industrial Revolution in the 18th century and industrialization, opportunities were created for machine production of goods, which also influenced their consumption, and the development of railway transport allowed for the easier movement of people, goods and materials and the expansion of already occupied territories, the assimilation of new ones. Agglomerations of settlements are formed, which attract people in search of better socio-economic conditions for life. Thus, for hundreds of years, the process of human development continues in modern times, in which mega cities with a population of more than twenty million people

appear. inhabitants (as of 2025), the most populous cities are: Tokyo, 37 million inhabitants; Delhi, 34.7; Shanghai, 30.5; Dhaka, 24,6; Cairo, 23; Sao Paulo, 22,9; Mexico City, 22.7; Beijing, 22.6; Mumbai, 22 mil. [1]. The briefly described evolution of the human species, along with all the positives arising from the social, economic, innovative and technological improvement of a society, is accompanied by several negatives, including uncontrolled extraction of natural resources, accumulation of large volumes of waste; environmental pollution; increasing the dangers of natural disasters; loss of biodiversity; depletion of non-renewable natural resources; irreversible impact on nature. Among all the above, uncontrolled extraction of natural resources, leading to the accumulation of waste, is a prerequisite for the manifestation of other adverse phenomena and consequences of human activity.

The above-mentioned so far expresses in the broadest context the importance of the topic under consideration and puts in the basis of this study waste, its disposal and the possibilities for their disposal to achieve sustainable development for society over time. This is derived in the context of the concept of sustainable development, which guarantees the efficient use of resources due to their non-renewability [2]-[4].

The definition of waste used in this study fully overlaps with the definitions provided by the OECD, the European Commission, and the Basel convention, according to which:

- Wastes are substances or articles from which their holder is disposed of, intends or is obliged to dispose of [5].
- Wastes are substances or objects, other than radioactive materials covered by other international agreements, which: i) are disposed of or are being recovered; or ii) are intended to be disposed of or recovered; or iii) are required, by the provisions of national law, to be disposed of or recovered [6].
- *""Wastes" are substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law"* [7, p.10].

In general, waste is by-products or substances resulting from various human activities, including those conducted in residential homes, industrial sectors, agricultural practices, and other traditional activities [8],[9]. In terms of the type of waste itself and the characteristics it possesses, there are different classifications [10],[11] structured based on the origin, composition, or properties of the waste. An example classification is the one developed by [12] (see Table 1).

Table 1. Sources of waste

	Waste generators
Industrial	Such as manufacturing and processing units in the food processing industry, cement plants, power plants, textile industry, etc.
Municipal	Household waste/garbage, public places such as workplaces, schools, shops, plastic bags, plastic bottles, food waste, clothes, damaged household items, etc. Various agricultural activities include fertilizers, pesticides, agricultural residues, poultry, and abattoirs, and many more.
Agriculture	Various agricultural operations may include fertilizers, pesticides, waste from farms, poultry houses, and slaughterhouses, etc.
Medical	Hospitals, clinics, veterinary clinics, and laboratories use surgical materials, needles, blood, body parts, medicines, dressings, and syringes.
Electronic (e-waste)	Telephones, TVs, music players, DVDs, CDs, computers, mobile phones, etc.
Radioactive	Nuclear explosion, nuclear/nuclear energy, mining of radioactive materials, etc.
Construction and demolition	Construction of roads, buildings, and houses and the demolition of old buildings and structures generate a lot of construction waste
Mining	Waste from mining operations, hazardous gases from explosions, etc.

Source: [12, p. 3], [13, p.2]

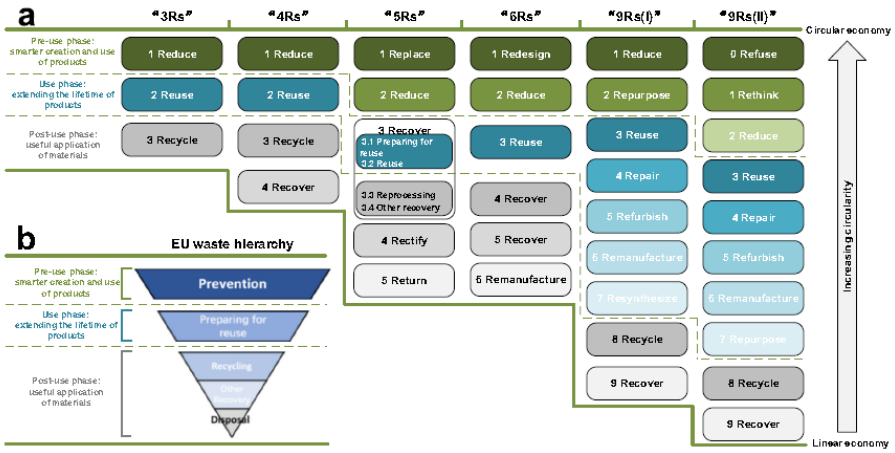
The main division of waste, from the point of view of ecology, is biodegradable and non-biodegradable [14], and without going into the essence of the classification features for the systematization of waste, for the purposes of this study we will limit ourselves to the separation of waste into non-hazardous or solid waste and hazardous waste.

Solid waste is heterogeneous and includes all materials and products that we produce because of our daily activities (packaging, bottles, devices, batteries, dyes, etc.) [15]. Their disposal into the environment can cause pollution of a different nature, which is why it is necessary to create conditions for their collection, transportation, and destruction [16]. According to its origin, solid waste is municipal solid waste, special waste and industrial (hazardous) waste. Municipal solid waste most often includes non-hazardous waste (except for batteries, dyes and other chemicals used in households), while special waste includes toxic, medical or radioactive waste. Industrial waste can include municipal or industrial waste [17].

Regardless of the type of waste generated, the main question facing society is how to deal with this waste without further negative impact on the environment. One of the first authors to raise the issue of the consequences of reckless and exploitative behavior of people, because of which natural resources are extracted, and waste accumulates in the environment is Boudling (1966) [18]. His work aroused interest among researchers [19]-[24], who further developed the idea of moving from the linear model of the economy (take-make-dispose) to a closed model of a circular economy, in which waste from one production is a raw material for subsequent use. Later, the issues of termination of the application of the linear model of economics were also analyzed in the works of [25]-[31].

In its original form, the concept of circular economy focuses on achieving a balance between the development of the economy and the environment [32]. It is defined as *"an economy based on a "spiral-loop system" that minimizes matter, energy-flow, and environmental deterioration without restricting economic growth or social and technical progress"* [33, p.74]. At its base is placed *„…the circular (closed) flow of materials and the use of raw materials and energy through multiple phases"* [24, p. 5]. Newer definitions, reflecting the development of the concept itself and expanding its scope, define it as *"an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes"* [26, p. 229] and more *"The circular economy is a multi-level resource use system that stipulates the complete closure of all resource loops. Recycling and other means that optimise the scale and direction of resource flows contribute to the circular economy as supporting practices and activities. In its conceptual perfect form, all resource loops will be fully closed. In its realistic imperfect form, some use of virgin resources is inevitable."* [34, p. 2]. Without going into an in-depth analysis of the definitive features and scope of application of the concept during the different stages of its evolution and accepting the author's definitions derived above, for the purposes of this study we formulate the following definition: **The circular economy is a closed system that combines the interests of stakeholders and environmental norms, minimizing the amount of resources used and maximizing the efficiency of their use to reduce the environmental footprint**. **The pursuit in this new economic system is aimed at maximizing the use of extracted and used resources while achieving a minimum of unused waste, which contributes to sustainable development for society.**

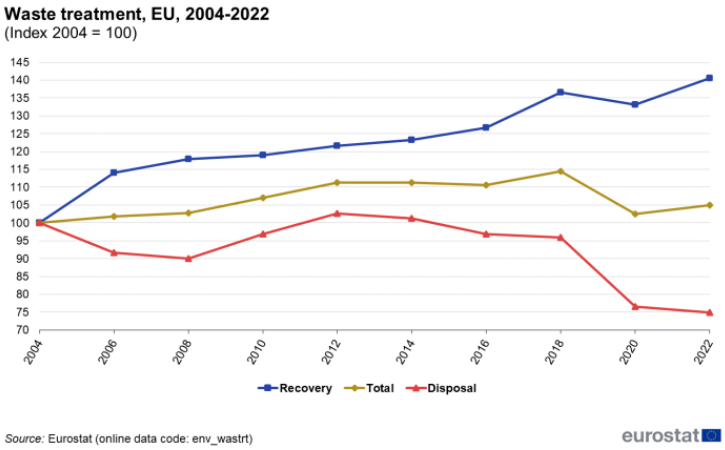
A key goal for the circular economy is to limit the amount of waste reaching the environment, on which the EC proposes Waste Framework Directive. She *„sets the basic concepts and definitions related to waste management, including definitions of waste, recycling and recovery* [5]. Its implementation and compliance with the evolution of the principles of the circular economy is expressed in Figure 1.



Source: [35, p.6]

Figure 1. Comparison of (a) circular economy and (b) waste hierarchy framework

As we can see from Figure 1, [35] link the stages in the development of the circular economy principles (3Rs, 4Rs, 5Rs, 6Rs, 9Rs) with the EU Wate Hierarchy, finding that the waste hierarchy has an impact on different practices for its management. The goal is to minimize the amount of waste reaching the environment by applying various principles of the circular economy [36]-[39] and reusing resources, materials, products, and waste. Data on the results of EU policy in this direction are presented in Figure 2.



Source: [40]

Figure 2. Waste treatment, EU, 2004-2022

The total amount of waste reaching the environment in EU countries decreased significantly in the period 2004-2022 (see Figure 2), at the expense of waste that passes through various recovery operations [11],[41],[42]. Regardless of the data provided, the residual amount of waste that is not subject to processing and recovery reaches the environment, which is why its disposal is necessary.

A review of the specialized literature shows an increased interest of theorists and practitioners in the issues of technologies used for solid waste disposal through thermal, biological and recovery methodologies or a focus on solid waste technologies used in a particular country, city or region [8],[9],[17],[43]-[51].

The methods applied since the 1970s have been analyzed by [43], focusing on the economic and environmental consequences of widely accepted methods of waste disposal: direct dumping of untreated waste in a sanitary landfill; processing of the waste before final disposal; and processing of

the waste to recover resources (materials and/or energy) with subsequent disposal of the residues [43, p.211). [49] provide a complete overview of innovative waste treatment and disposal technologies (improved concepts for plasma gasification, transmutation, incineration, biorefineries, microbial fuel cells – MFC), including a full description of the different processes for managing solid, liquid, gaseous and radioactive waste. The main technologies for tackling municipal waste falling within the scope of the analysis of [50] include composting, incineration and landfilling, and attention is also paid to innovative technologies for energy recovery in waste incineration [52]-[54].

Territorially applied waste disposal practices were examined in study of [44]. They compared the social costs of two of the most applied waste disposal methods in the Netherlands, incineration, and landfill, finding that landfilling is a more economical method in terms of reducing social costs. India's leading innovative waste disposal mechanisms (composting and conversion of energy from waste by incineration) are the subject of research by [8], while [45] focuses on biomedical waste, the extent of its generation by category, segregation, labeling, treatment, treatment and methods of disposal of residues [45, p. 787], as well as technologies for their disposal. The experience of developing countries in municipal waste disposal is presented by [47], focusing on the lack of financial resources for the construction of processing and disposal stations, which is why the most common practice is open disposal or open incineration of waste, which is contrary to sustainable development and environmental protection policies. [51] analyse the waste disposal methods applied in Kuwait and identify the priority use of practices such as composting and incineration (refuse-derived fuel – RDF combustion) that are consistent with environmental sustainability, specific infrastructure, and technical feasibility in the Gulf region. [55] narrow the scope of the study by specifically analysing the landfill opportunities for waste generated by oil/gas drilling in salt mines in China, preparing a systematic summary and practical proposals for the successful implementation of the technology and the improvement of necessary laws and policies.

In another direction is the research of [17], [46], [48] whose focus falls on the process of choosing a specific technology for waste disposal. [46] proposes an approach to selecting a municipal solid waste disposal plant tailored to the type of its owner or operator. [17] evaluated ten alternative solid waste disposal technologies using eighteen criteria formulated by Istanbul Environmental Management Industry and Trade Co., Ltd. to determine the most efficient waste treatment technology. A similar idea is applied by [48], whose analysis focuses on the use of a multi-criteria method in the decision-making process for the choice of technology for long-term use in waste disposal.

The limited review of the existing literature in the field of solid waste disposal is indicative of the importance of waste treatment technologies for minimizing harmful substances reaching the environment. The presented research presents descriptive of the existing problems seeking a solution among the academic community and reveals the trends in the development and application of waste disposal methods. At the same time, insufficient attention is paid to patent statistics as an indicator of technological changes and to patent activity in the field of waste disposal.

Therefore, the purpose of this study is to study patent statistics indicating the development of technologies in the field of waste disposal, which contributes to reducing the footprint and negative impact of people on the environment.

The object of research is waste disposal, and the subject of research is patent statistics as an indicator of technological changes in the field of waste disposal.

The research question that we will try to answer through the research is: *In which technologies are the inventive capacity concentrated to limit the negative impact of the waste already generated and expected in the future?*

Considering the stated goal and the formed research question, the study will focus on the following working questions:

1: What is the structure and dynamics of patent activity conducted during the research period?

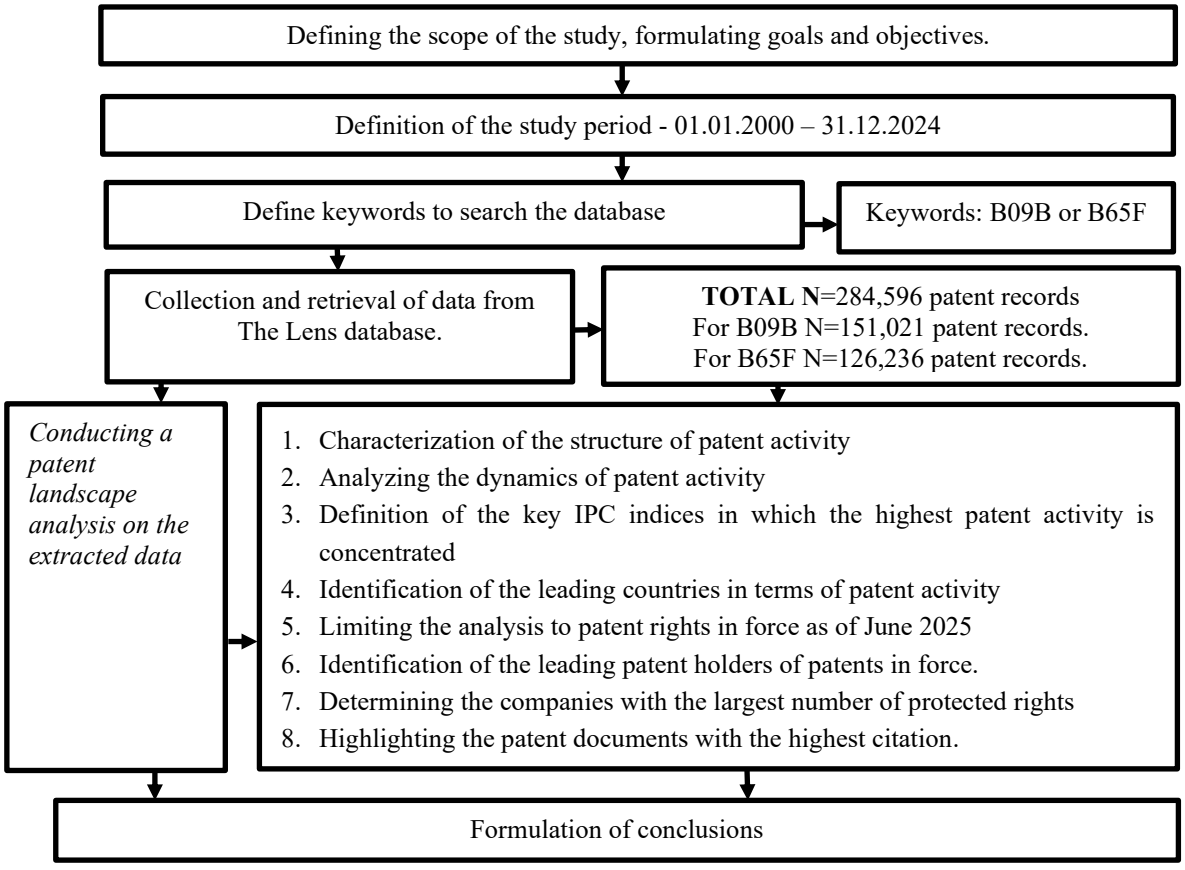
2: What are the priority classes under the IPC that patent activity is aimed at, i.e., which are the technologies that are developing the fastest?

3: Which are the leading patent holder countries?

These questions will contribute to clarifying technological developments in the field of waste treatment.

Materials and methods

To conduct the study, we use patent landscape analysis (PLA) [56]-[59]. Through it, we identify not only the trends of technological development, but also the main participants and innovators in the field of waste disposal. According to [59] PLA examines the protected rights to innovative developments in a specific technological area to identify trends over time, since it is characteristic of this type of research that they are retrospective in nature. This follows from the specifics of the patenting process, in which the first patent documentation is published at the earliest eighteen months after the filing of the patent application. On the other hand, patent documentation is also seen as an early indicator of upcoming technologies that are expected to enter the market through the implementation of patented technology in innovative products. PLA can reveal the existing links between technology classifications (classes); organisations; locations of R&D; markets/regions potentially considered to be of value for certain organisations/technologies and other patent/technology characteristics [59]-[62]. PLA is based on technological classifications through which patents can be searched and grouped. In this study, we adhere to the use of International Patent Classification (IPC) [63].



Source: *elaborated by the author*

Figure 3. Steps involved in the analysis.

The scope of the study in the field of waste disposal extends to the category of Environmentally Friendly Technologies (WIPO) [64] included in the list of the United Nations Framework Convention on Climate Change (UNFCCC). Environmentally sound technologies are defined by a Committee of

Experts of the IPC, which indicate all IPC classification codes that can be assigned to a particular category of technologies. For the purposes of this study, we will analyze data concerning waste disposal technologies, in particular the indexes ***B09B*** *(DISPOSAL OF SOLID WASTE NOT OTHERWISE PROVIDED FOR)* and ***B65F*** *(GATHERING OR REMOVAL OF DOMESTIC OR LIKE REFUSE)* falling within their scope [64].

The data required to conduct PLA are extracted from The Lens Database [65] and include patent documents issued in the period 01.01.2000 – 31.12.2024. After applying an online search carried out in February 2025, we examined a total of 284,596 patent records, of which 151,021 patent documents and 101,682 single patent families to which the IPC B09B index is assigned and 126,236 patent documents and 104,577 patent families to which the IPC B65F index is assigned.

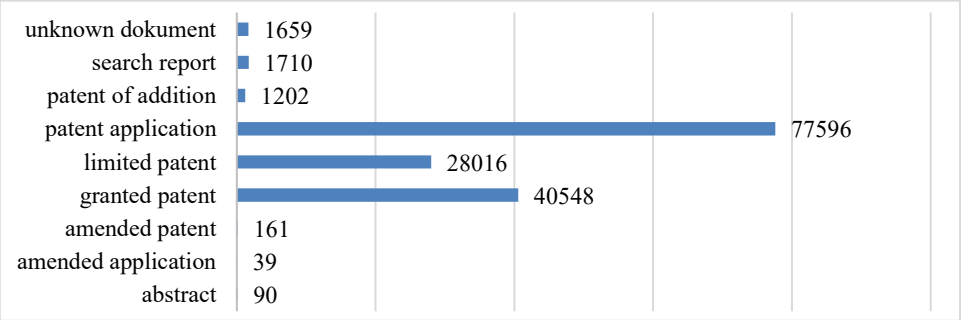
The model of the study is presented in Figure 3.

The results of the analysis are presented using *a graphical method* to illustrate the indicators studied and to reveal the dynamics and trends in their development, as well as *a comparative method* to compare the patent activity conducted by different countries in the analyzed classes under the IPC.

Results

Patent analysis of technology for disposal of solid waste not otherwise provided for (B09B)

The distribution of total patent activity by index *B09B* (151,021) and by type of issued security documents is expressed in Figure 4.



Source: compiled by the author based on data from [65]

Figure 4. Types of patent documents of technology for disposal of solid waste not otherwise provided for (B09B)

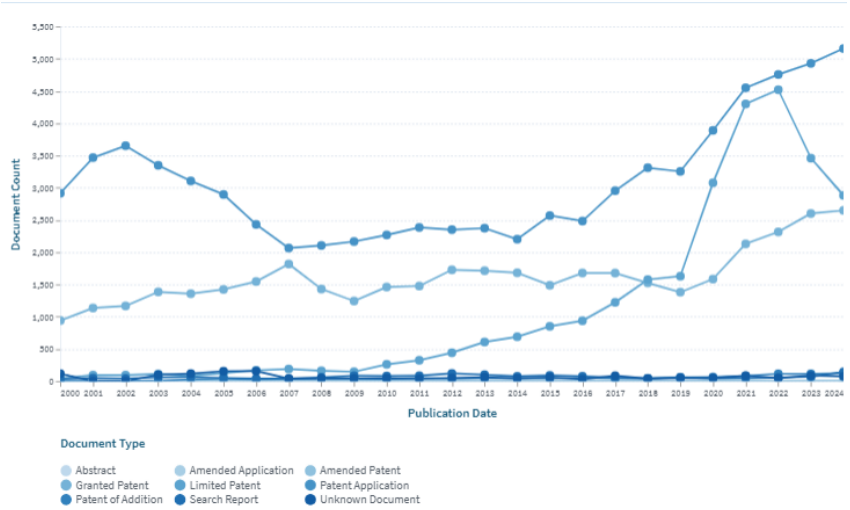
Three categories of patent documents are of the greatest importance for this analysis, forming 96.78% of the total patent activity – patent applications, granted limited patents for utility models (28.016). We also found the strongest dynamics during the study period (see Figure 5).

The dynamics of the total patent activity in the field of solid waste disposal technologies not otherwise provided for (B09B) is presented in Figure 5.

From the graphical presentation of the data on the applications submitted in the period 2000-2024 (a total of 77,596 for the study period) for patenting technologies for solid waste disposal, which is not otherwise provided for (B09B), we find two stages of development – until 2007, when, after the reported growth in the number of applications for granting a patent in 2000 and 2001, we observe a decrease in activity until 2007, on average by 10.68% per year. The second stage (from 2008 to 2024) is characterized by a gradual increase and activation of the applicant activity, which, despite some fluctuations in individual years, grows by an average of 5.82% per year. The average annual change for the entire study period is an increase of 2.9%.

For the granted patents (40,548) in the period 2000-2024, trends are observed, influenced by the established dynamics in application activity. A noticeable decrease in the number of granted patents was reported in 2008 and 2009, with an average annual decrease of 17.17%. The next period of slowdown in patent activity was from 2013 to 2019, when a decline was reported, on average by

2.85% per year. Nevertheless, in the period 2000-2024, an overall positive trend of growth in the issued patents is maintained, with an average annual growth of 5.18%.

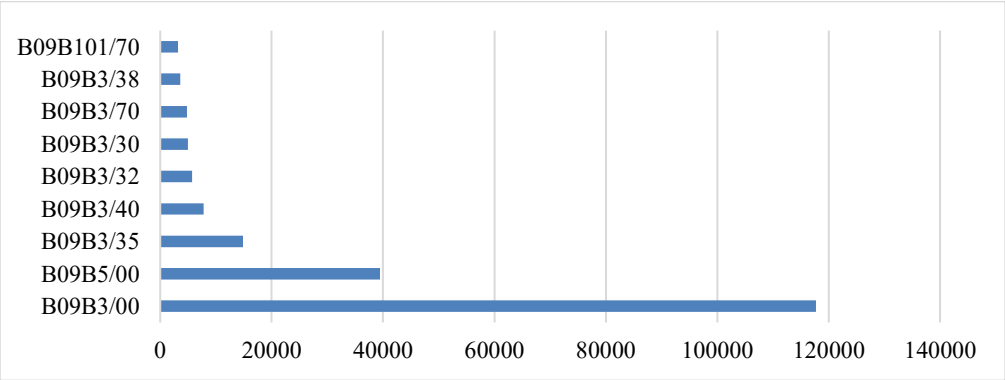


Source: compiled by the author based on data from [65]

Figure 5. Dynamics of patent activity of technology for disposal of solid waste not otherwise provided for (B09B)

Limited patents, for which in some countries there is no provision for independent protection as an object of industrial property, are the category in which we find the strongest development in the study period – growth, on average by 23.65% per year. The largest decline in the issued rights to utility models was reported in 2004 compared to 2003 (25.89%), and the strongest growth in 2001 compared to 2000 (123.26%). The highest level of activity of restricted patent holders reached in 2022 (4520), which is 105 times more than in 2000 (43).

After analyzing the IPC indices reflecting the technological directions for the application of innovative technologies for disposal of solid waste not otherwise provided for (see Figure 6), we find that the highest concentration of innovative developments (117,740 documents) is B09B3/00 Destroying solid waste or transforming solid waste into something useful or harmless. The inventive interest found is not a surprise to us, as solid waste is at the root of environmental pollution and is a widespread problem in both urban and rural areas of developing and developed countries [66].



Source: compiled by the author based on data from [65]

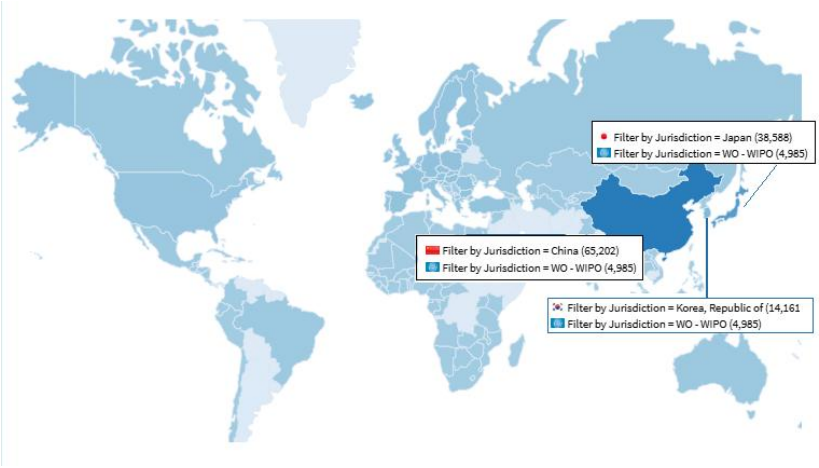
Figure 6. IPC codes of technology for disposal of solid waste not otherwise provided for (B09B)

Next in terms of concentration of patent documents is index B09B5/00 **Operations not covered by a single other subclass or by a single other group in this subclass** (39,481), and the third is B09B3/35 Shredding, crushing or cutting (14,879), including innovations in a certain type of waste shredding technologies.

The distribution of patent activity in the other IPC indices included in the analysis is as follows:

- B09B3/40 – involving thermal treatment, e.g., evaporation (processes using mineral binders involving a melting or softening step B09B3/29; involving radiation B09B3/50) – 7,781 pc.
- B09B3/32 – Compressing or compacting – 5,740.
- B09B3/30 – involving mechanical treatment (involving an extraction step B09B3/80) – 4,969.
- B09B3/70 – Chemical treatment, e.g., pH adjustment or oxidation (involving an extraction step B09B3/80) – 4,790.
- B09B3/38 – Stirring or kneading – 3,595.
- B09B101/70 - Kitchen refuse; Food waste – 3,199.

The contribution of individual countries to the formation of the concentration of patent rights thus established is presented in Figure 7.



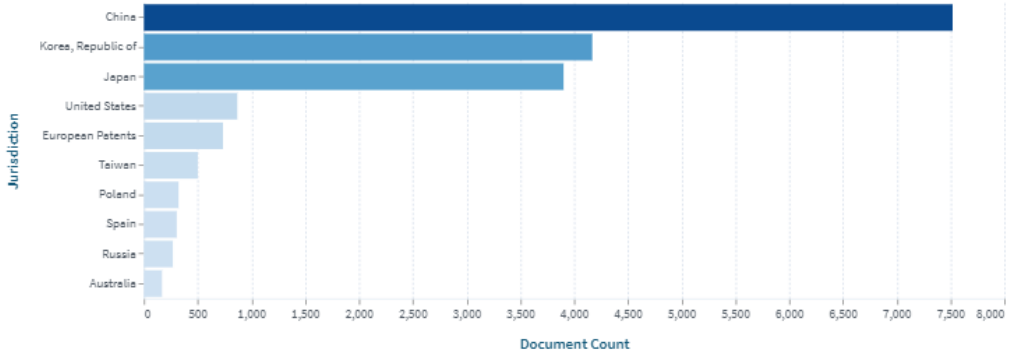
Source: compiled by the author based on data from [65]

Figure 7. Contribution of individual countries to the formation of patent activity for technology for disposal of solid waste not otherwise provided for (B09B)

The graph (see Figure 7) is indicative of China's development and active participation in the development of technologies for disposal of solid waste not otherwise provided for (B09B) – they own 43.17% of all patent documents. Next in terms of activity is Japan, with a total contribution of 25.55% and South Korea with 9.38%. Thus, the first three countries form a share of 78.10% in the structure of patent activity. Although the European Union (EU) is actively involved in the development and implementation of environmental protection policies and the introduction of the principles of circular economy and sustainable development, the contribution to the development of technologies for disposal of solid waste not otherwise provided for (B09B) is only 3.38%. This is followed by WO-WIPO and the United States, with 3.30% and 2.77% shares, respectively. The other seventy-five countries for which we have extracted data from The Lens Database have less than 2% participation in the formation of patent activity.

In the subsequent part of the analysis, we will limit ourselves to analyzing the information concerning the patent rights still in force (June 2025). Out of a total of 54,032 patent documents, 20,113 are granted and active patents, 15,748 are limited patents, and patent applications are 16,829.

From the analysis of the data in The Lens Database [65], we find the countries from which the patent holders originate, which have the largest number of active patents. China (7,520), South Korea (4,169), and Japan (3,902) have the highest concentrations of active granted patents (see Figure 8).



Source: compiled by the author based on data from [65]

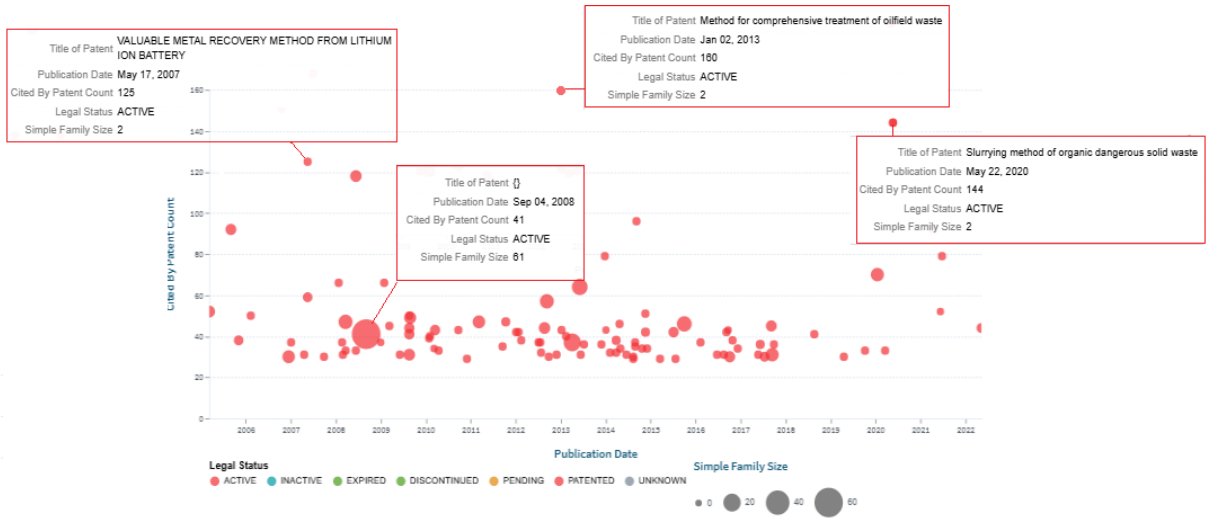
Figure 8. Patents granted (active) by patent owner country for technology for disposal of solid waste not otherwise provided for (B09B)

Structurally, 73.3% of the companies, forming this activity, are headquartered in Japan, 13.3% represent China (from the Higher Education sector), 6.7% from South Korea and 6.7% from France.

Analyzing the citation rate of active patents during the research period, we establish the technological impact of inventions, which also affects their economic importance, since the number of citations reflects the technological and commercial importance of the patented innovation [67]. From the data available to us (see Figure 9), we find that the patent for a method for the complete treatment of oil field waste, which has 160 citations, is distinguished with the highest recognition, but the single family (a group of patent documents arising from the same initial priority document, providing legal protection on the territory of different countries [68]) consists of only two documents.

The largest patent family is formed from sixty-one documents providing broad legal protection for a Japanese patent "Batch Biomass Processing System and Biomass Treatment Process".

Figure 9 is indicative of the citation of the other active patents, but due to the limited scope of the present development, we refer only to the data for some of them.

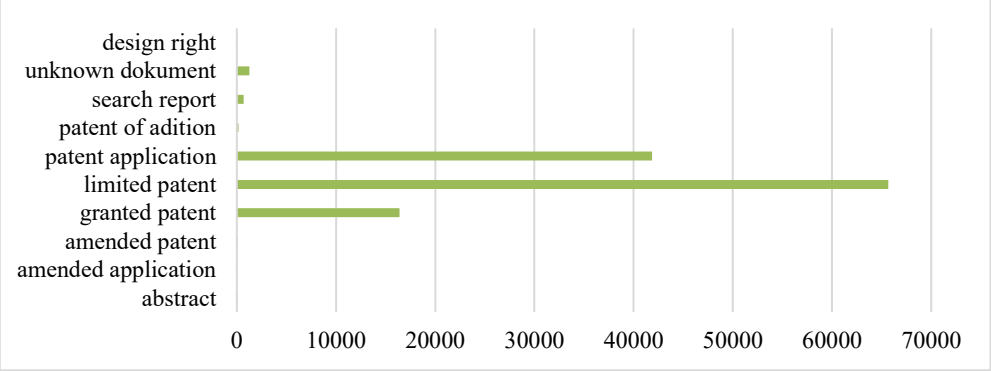


Source: compiled by the author based on data from [65]

Figure 9. Citation of patents in the field of technology for disposal of solid waste not otherwise provided for (B09B)

Patent analysis of technology for gathering or removal of domestic or like refuse (B65F)

The distribution of the total patent activity (126,236) by type of issued documents from index *B65F* is illustrated in Figure 10. As we found in the case of B09B technologies, patent applications, granted patents and limited patents for utility models are of the greatest importance, forming 98.2% of the total issued documents.



Source: compiled by the author based on data from [65]

Figure 10. Types of patent documents of technology for gathering or removal of domestic or like refuse (B65F)

The evolution of patent activity in the field of technologies for the collection or removal of municipal or similar waste (B65F) is presented in Figure 11.

Source: compiled by the author based on data from [65]

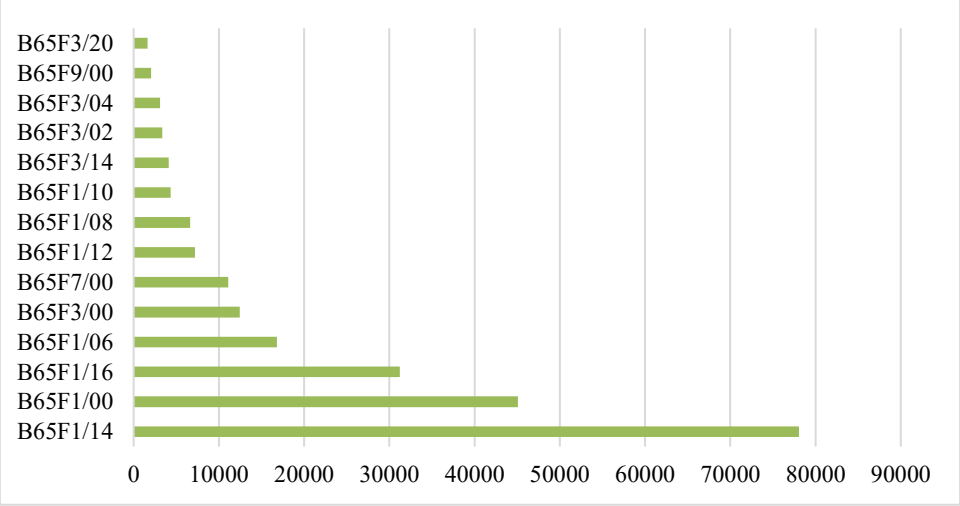
Figure 11. Dynamics of patent activity of technology for gathering or removal of domestic or like refuse (B65F)

The data on the patent activity conducted in the period 2000-2024 express the commitment of inventors in the field of technologies for the collection or transportation of household or similar waste (B65F). The applications filed are a total of 41,849, and for the entire period we report an increase in the rights applied for protection, on average 4,61% per year. Nevertheless, we observe two periods of decrease in activity – from 2006 to 2008, when the average annual decline reaches 12.79% and from 2022 to 2024, with an average annual decrease of 20.6%.

For the granted patents (16,390), the overall dynamics expressed a positive change, on average by 4.68% annually in the period 2000-2024. The fewest patents were issued in 2009 (306 pcs.) and the most in 2022 (1,434).

Restricted patents are the preferred form of protection of rights in the field of technologies for the collection or transportation of household or similar waste (B65F). For the period 2000-2024, 65,680 limited patents for utility models were registered, the highest level of which we report in 2021 (11,375) and the lowest in 2002 (295 pcs.). Although there is a negative change in the number of limited patents issued in individual years of the analyzed period, the strongest negative trend is reported from 2022 to 2024, the average annual decrease is 26.45%. The change that we report throughout the study period is growth, on average, of 16.09% per year.

Analyzing the IPC indices (see Figure 12), we reveal the technologies for collection or transportation of household or similar waste (B65F), in which there is the widest interest on the part of inventors. First in terms of concentration of patent documents is B65F1/14 Other constructional features (holders or carriers for hand articles A45F5/00; fastening devices for wings E05C; hinges E05D) with 78,052 documents, followed by B65F1/00 Refuse receptacles (containers not specially adapted for refuse, features of refuse receptacles of general interest B65D) – 45,074 documents, and B65F1/16 Lids or covers (pedal or hand-lever operated B65D) – 31,234 documents.



Source: compiled by the author based on data from [65]

Figure 12. IPC codes of the preferred technology for gathering or removal of domestic or like refuse (B65F)

The other IPC indices in which there is the most expressed interest are:

- B65F1/06 – with flexible inserts, e.g., bags or sacks – 16,824 pcs.
- B65F3/00 – Vehicles particularly adapted for collecting refuse (vehicles in general B60; driving vehicle equipment or auxiliaries B60K; discharging contents by tilting entire vehicles B65G; wheeled apparatus for emptying sewers or cesspools E03F7/10)– 12,460.
- B65F7/00 – Cleaning or disinfecting devices combined with refuse receptacles or refuse vehicles (such devices per se A61L, B08B) – 11,116.
- B65F1/12 – with devices facilitating emptying – 7,199.
- B65F1/08 – with rigid inserts – 6,646.
- B65F1/10 – with refuse filling means, e.g., air-locks – 4,357.
- B65F3/14 – with devices for charging, distributing, or compressing refuse in the interior of the tank of a refuse vehicle (B65F3/02 takes precedence) – 4,101.
- B65F3/02 – with means for discharging refuse receptacles thereinto (conveyor construction B65G; loaders separate from vehicles B66F; fluid power control systems in general F15B) – 3,353.
- B65F3/04 – Linkages, pivoted arms, or pivoted carriers for raising and subsequently tipping receptacles – 3,094.

- B65F9/00 – Transferring of refuse between vehicles or containers with intermediate storage or pressing (presses for baling per se B30B9/30) – 2,047.
- B65F3/20 – with charging pistons, plates, or the like (for discharging B65F3/28) – 1,642.

The contribution of individual countries to the formation of the concentration of patent rights for technologies for the collection or removal of municipal or similar waste (B65F) is shown in Figure 13.

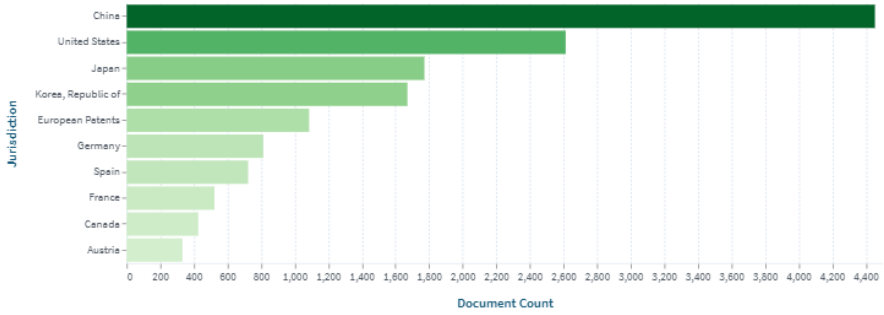
Source: compiled by the author based on data from [65]

Figure 13. Contribution of individual countries in the formation of patent activity for technologies for gathering or removal of domestic or like refuse (B65F)

The graph (see Figure 13) reveals China's superiority in the number of patent documents issued (67.9%) in the field of Waste Disposal. Next in terms of activity, as we found in technologies for disposal of solid waste not otherwise provided for (B09B), is Japan, with a total contribution of 5%, the United States, with 4.6% and South Korea with 4.2%. The share of the first four countries in the overall structure of patent activity (73 countries) is 81.7%.

Following the model of the study, here we will narrow its scope, and in the subsequent part of the analysis we will limit ourselves to the information about the patent rights currently in force (June 2025). Out of a total of 44,561 patent documents, 9,181 are active patents, 8,046 technology rights have been filed, and 26,869 limited patents have been granted. This allocation reiterates the leading role of utility models and brings them to the preferred form of legal protection for innovative developments for technologies for the collection or removal of municipal or similar waste (B65F).

From the analysis of the data in The Lens Database, we derive the countries of origin of the patent applicants with the largest number of patents granted and still active (Figure 14). Among them are China with 4,454 patents, the United States (2,613), Japan (1,772), South Korea (1,671), and EPO patents (1,086).

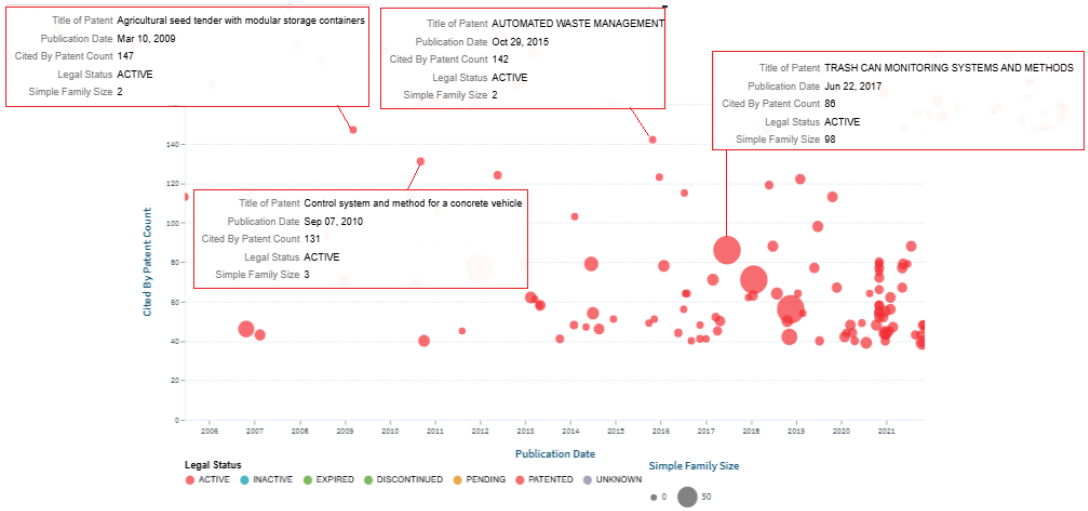


Source: compiled by the author based on data from [65]

Figure 14. Patents granted (active) by country patent holders technologies for gathering or removal of domestic or like refuse (B65F)

The structure of application activity under the B65F classification index differs from that already established for B09B. Here there is a higher degree of heterogeneity in terms of filings. The largest share is China (33.3%), formed by representatives of business and higher education. Companies based in Japan form 20%, and those from the USA – 13.3%. Canada, Finland, Germany, and the United Kingdom have a share of 6.7%.

The citation of the analyzed protected patent rights (see Figure 15) expresses the importance of the developed technologies and the possibility of economic realization. The most widely cited and enshrined patent documents (147 citations) of those in force at the time of the analysis is a patent with the number US 7500817 B2 for "Agricultural seed tender with modular storage containers". Another patent with high citation is the US 2015/0307273 A1 patent for "Automated Waste Management".



Source: compiled by the author based on data from [65]

Figure 15. Citation of patents in the field of technologies for gathering or removal of domestic or like refuse (B65F)

The largest patent family is formed by ninety-eight documents providing broad legal protection for the American patent "Trash Can Monitoring Systems and Methods". With the same number of documents in a single patent family are two more priority documents for Shopping Facility Assistance Object Detection Systems, Devices and Methods and for Shopping Facility Assistance Systems, Devices and Methods, again owned by American companies.

Discussion and conclusion

An essential moment in our development as a society is the achievement of awareness of the impact we have on the environment. In this study, we have tried to theoretically clarify the relationship between the development of society as a prerequisite for the formation of waste and a motive for transforming the linear model of the economy into a closed cycle (circular economy model), which will contribute to limiting waste reaching the environment and achieving sustainable development. At the same time, we put waste disposal technologies at the centre of society's progress in this direction. Through the prepared review of the specialized literature in the field of waste disposal technologies, we have proven their importance for limiting the negative impact of people on the surrounding nature on the one hand and on the other, preserving natural resources and providing sustainable conditions for the development of future generations.

The formulated research question, which reads *"In which technologies are the inventive capacity concentrated in order to limit the negative impact of waste already generated and expected in the*

future?" determined the next steps in the research model, because of which we formulated the relevant conclusions.

The analysis of the patent documents under the IPC classification indices (***B09B*** and ***B65F)*** falling within the scope of Environmentally Sound Technologies for Waste Disposal showed that more inventive capacity was directed to technologies from index ***B09B*** for disposal of solid waste not otherwise provided for (151,021 patent documents) compared to technologies from index ***B65F*** – technologies for gathering or removal of domestic or like refuse (126,236).

The distribution of the total patent activity by index **B09B** for the period 2000-2024 shows that the largest number of documents is observed in three categories, forming a 96.78% share of the total patent activity – patent applications, granted patents and utility models. Tracing the dynamics of the issued documents, there is a growth trend in all three categories, with the most noticeable growth in utility models, The average annual change in which is 23.65%. The number of granted patents is growing on average by 5.18% per year, and the average annual change in the filed patent applications is 2.9%. The above proves that the development of technologies for the disposal of solid waste, which is not otherwise foreseen, continues to engage the minds of inventors.

The analysis of the IPC indices reflecting the type of technology specifically developed shows that the highest concentration of innovative developments (117,740 documents) is B09B3/00 Destroying solid waste or transforming solid waste into something useful or harmless, followed by B09B5/00 Operations not covered by a single other subclass or by a single other group in this subclass (39,481) and B09B3/35 Shredding, crushing or cutting (14,879).

In terms of the source of patent activity, China has the most active participation in the development of research technologies, where 43.17% of all patent documents originate. Japan (25.55%) and South Korea (9.38%) follow this.

As of June 2025, the patent rights in force are concentrated in patent holders from China (7,520), South Korea (4,169), and Japan (3,902). Structurally, 73.3% of patent holder companies are headquartered in Japan, 13.3% represent China (from the Higher Education sector), 6.7% from South Korea and 6.7% from France.

Although the overall patent activity under the **B65F** index is weaker than the one already established for the B09B index, here again the highest concentration (98.2% share) of documents is observed in the same categories – patent applications, granted patents and utility models. Again, from the dynamics of patent activity in each of these categories, we find a positive trend of growth in activity, which is highest in the case of limited utility model patents. The average annual change in the period 2000-2024 is 16.09%, while in the granted patents it is 4.68% and in the filed applications 4.61%.

The widest interest of inventors in the field of technologies for the collection or removal of household or similar waste (B65F) is shown in B65F1/14 Other constructional features (holders or carriers for hand articles A45F5/00; fastening devices for wings E05C; hinges E05D) with 78,052 documents, followed by B65F1/00 Refuse receptacles (containers not specially adapted for refuse, features of refuse receptacles of general interest B65D) – 45,074 documents and B65F1/16 Lids or covers (pedal or hand-lever operated B65D) – 31,234 documents.

The most significant place in the formation of patent activity has: China (67.9% of patent documents issued), Japan, with a total contribution of 5%, the United States, with 4.6% and South Korea with 4.2%. The share of the first four countries in the overall structure of patent activity (73 countries in total) is 81.7%.

The patent rights for inventions in force as of (June 2025) are concentrated in inventors from China with 4,454 patents, the United States (2,613), Japan (1,772), South Korea (1,671), and EPO patents (1,086).

The structure of the application activity according to the B65F classification index is characterized by a high degree of heterogeneity in terms of the source of the submitted applications. The largest share is China (33.3%), formed by representatives of business and higher education. Companies headquartered in Japan account for 20 percent and those from the United States account for 13.3

percent. The rest of the companies from France, Canada, Finland, Germany, and the United Kingdom have a share of 6.7%.

In conclusion, what has been described so far, we can summarize that the priority for inventors in the field of waste disposal technologies of the B09B and B65F indices is limited patents for utility models. The analysis testifies to China's leading role in the development and protection of utility models, with Chinese holders registering 25,759 restricted patents under the B65F classification index and 15,172 limited patents under the B09B index. c: the fast-track process for obtaining a utility model protection certificate under certain national laws (its duration is a maximum of 10 years); in the lower fees for registering a utility model and maintaining its operation; in cases where the innovative technology does not have the character of an invention, the economic potential of which can be extracted for the entire period of patent protection (20 years); in technologies with a shorter life cycle.

In summary, this paper is an in-depth analysis of patent activity in the field of waste disposal technologies in the period 2000-2024, which contributes to identifying the existing trends and outlining conclusions about the inventive activity during the selected research period.

Outside the present study, the questions about the application of patented technologies, constituting the established technological capacity, in waste disposal practices. The rate of adoption of innovative technologies is an indicator of the commitment of political power, companies, the public and the individual in the fight against pollution. This implies the need and opportunity for our subsequent research interests to focus on the capacity of individual countries to absorb and apply the innovative technologies for waste disposal revealed in this study.

It should be noted that the analysis prepared is based on the information from the patent documents extracted through The Lens Database [65] and there may be a discrepancy between the real data and what is indicated in this study due to the lack of information or inaccuracies in the digitized patent documents and records themselves.

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