How patents support the development of new technologies in waste management

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Abstract. This article discusses the main trends in the dissemination of the results of intellectual activity on the impact on the environment of industrial and household waste. Particular emphasis is placed on the analysis of patent activity in the countries of the European Union, OECD and Russia. We consider the patent as a tool of new technologies in the struggle for environmental cleanliness during the transition to a circular economy. A circular economy is an economy with advanced technology, sustainable development, and a production culture that grows through inventive activity. The article presents the results of an analysis of the state of patent activity by country in dynamics from 1990 to 2018-2019. At the same time, we conducted a study of the factors influencing patent activity using regression analysis and identified the most significant factors affecting the resulting indicator.

1 Introduction

New technologies are becoming the basis of economic development in the 21st century. The introduction of innovations is an important factor in the economic development of any state. Scientific and technical developments in the form of inventions and patents help accelerate the process of technology transfer to the real sector of the economy.

They are able to raise any direction to a higher level, both of individual manufacturing companies and the economy as a whole. Sustainable development of the economy is the balanced development of three elements: ecology, economy and social sphere. Among these three dimensions, environmental safety is a key condition for the realization of all other goals. Wastewater treatment, utilization of household and industrial waste, and the use of waste material as energy are the dominant trends in the circular economy. The development of these areas can ensure the sustainable development of the country.

Today, environmental issues are the most important task for all mankind. The presence of an effective portfolio of patents in the country contributes to the active development of innovations in various fields, including in the field of ecology and nature conservation According to the Paris Convention for the Protection of Industrial Property, "the availability of patents is an indicator of technology development" [1]. Patents are a key indicator of innovation and reflect a country's inventive activity. [2]

In recent years, the vector of patent activity has shifted towards recycling secondary raw materials into a material suitable for reuse, obtaining alternative energy sources, fuel from waste, etc. [3-6]. The European Union owns 30% of the world's patents for the production and use of alternative energy sources. Moreover, 20% of them come from biofuel, which is obtained as a result of waste processing. [7]

According to expert estimates of a special working group at the OECD on ecology and environmental protection 70% of all industrial waste and emissions can be reduced through the use of innovative technologies for processing, recovery and reuse of waste materials. [8]. The current trend has the propensity to push inventors to work in this direction, i.e. for research in terms of waste recycling.

Developing and implementing innovative technologies for waste recycling is an important condition for the country's participation in a global environmental policy. In this sense, patents are a driving force and a tool to stimulate innovation.

In the European Union, the USA, and Japan a very high degree of sorting of waste and the extraction of useful materials has been carried out for some time now, which is subsequently recycled back into manufacturing. [9] For example, the German company Werner & Mertz GmbH became the first organization to process PET bottles and PET films. As part of its initiative, the company produces regranulates from PET waste for the production of bottles for packaging detergents. [10]

Some polymer converters go further and along with in-process recycling and direct return of their production waste to the process, use recycling plants to make secondary granulates from their waste. For example, Poliflm Extrusion GmbH (Weisandt-Gelzau, Germany) annually produces 25 thousand tons of secondary granulate for the subsequent cost-effective production of garbage bags, agricultural and construction materials from it. [10]

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In both developed and developing countries, innovation is gaining momentum and expanding rapidly. This is evidenced by the trend of changes in R&D expenditure. According to research from Cornell University in the framework of a joint project of the International Business School INSEAD and the World Intellectual Property Organization, there is a steady increase in global R&D spending (for general purposes), which includes both state budget allocations and enterprises' own funds. In the period from 1996-2016 the amount of these expenses has more than doubled. The decline in activity in 2009 due to the global financial crisis led to a drop in all economic indicators, including spending on science. However, by 2017 the situation had leveled off and the growth rates in the public sector amounted to about 5%, and the volume of expenses for these purposes in the business sector - by 6.7% (Fig. 1). [11].

Fig. 1. R&D expenditure growth, 2000-2017 [11].

Modern society especially needs the development of innovative activities in the field of technologies associated with the need to preserve the human environment. This is the creation of environmentally friendly and waste-free industries, technical capable of monitoring the state of the environment; use of renewable energy sources and other technologies.

Object of research: development of the concept of household and industrial waste management in the developed countries of the world.

The subject of the study is the fundamental factors that determine the principles of waste management in the OECD countries.

Hypothesis: the existence of a statistical relationship between the performance indicators of patent activity and socio-economic indicators of economic development has a direct impact on innovative activities in the field of waste management.

The purpose of the study: to analyze the dynamics of patent activity in the field of waste management using data from collection, recycling of household and industrial waste in the leading OECD countries and to determine the main factors affecting patent activity.

2 Materials and methods

Patent statistics are a reliable indicator of a country's innovation performance. The possession of patents in the field of waste management is an indicator of innovation for tracking changes in technologies associated with changes in the environment. [12-13]

The statistical analysis of the leading countries and Asian countries with data of patent activity in Russia showed that the total number of patents over the last 8-10 years decreased in almost all countries (table 1). 2006-2011 are the most technologically advanced years, after these years in many countries there is a decrease in the peak of patent activity. [14]

Compared to 2017 in 2018 indicators remain stable in Japan, the growth rate of the number of registered patents in which was 109.0%, Australia - 99.1%. In Germany, the USA and Canada, the decrease in inventive activity is more than 20%. In other countries the decline is even more significant.

China has the led the field for many years. Compared to 2017 the growth rate was 21.8%, while compared to 1990 this figure increased six times. Japan in 2010 yielded its leadership position to China. The Republic of Korea has a stable position and for several years now has been ranked third in terms of the number of patents available, although inventive activity has slightly decreased (70.5%) compared to 2010.

Table 1. Availability of patents in the field of waste management [14, 15].

Country	1990	1995	2000	2005	2010	2015	2018
Canada	469	446	452	588	680	618	576
Japan	1740	4028	6797	3855	2531	1903	1658
Korea	198	433	1236	1734	2353	1936	1706
USA	842	1447	1231	2083	1849	1960	1570
Australia	316	532	758	400	551	460	543
China	137	375	752	1600	4349	12851	28879
Germany	814	991	732	496	337	283	183
Austria	369	348	360	210	51	25	2
Czech	…	116	90	34	34	17	14
Russia	…	248	296	378	458	510	325

China's successes is due to the fact that state allocations for R&D are constantly growing, reforms in the field of science are being carried out in the country, and legal rights are being presented to private business. According to the Xinhua agency, the Statistics Office of China, R&D expenditures in China amount to $ 280 billion, and these are record figures with high growth rates. [16]. As can be seen from the data in Table 1, there is no data for 1990 for Russia, the Czech Republic (and individual countries of Eastern Europe). This is due to the time during which Russia and the countries of the socialist camp of eastern and central Europe were just transitioning to a market economy. Political and economic reforms of the 90s did not allow these countries to deal with environmental issues on a full scale. Therefore, at the turn of the last century, there is a significant lag in the number of patents not only in Russia, but also in other countries of the former socialist camp.

Despite a slight slowdown in patent activity in recent years, in general, the average annual growth over 18 years in the world's leading economies amounted to more than 6% per year.

The structure of distribution of patent activities in the areas of waste management is stable across countries. The bulk of patents related to waste management are for inventions that relate to the recovery, recycling and reuse of waste. China accounts for the largest number of such inventions (Table 2).

Table 2. Material recovery, recycling and reuse [14].

Country	1990	2000	2005	2010	2015	2018
Canada	197	197	214	241	263	258
Japan	586	1799	1231	1037	869	703
Korea	198	1236	1734	2353	1936	1706
USA	303	571	827	855	917	848
Australia	122	329	143	216	186	209
China	74	351	723	858	6342	10979
Germany	313	310	217	166	116	80
Austria	114	155	87	35	13	13
Czech	…	15	4	6	2	1
Russia	…	154	169	250	289	138

In nominal terms, Russia has a disproportionately small share: only 3% relative to the data of China. Japan has similar developments 46.2%, more than Russia, the USA - by 38.3%, Korea - by 19.1%. The reasons for this lag is the lack of financial investment from the private sector, insufficient funding for research and development from the state, complexity of legislation in the field of registration for intellectual property. Russian entrepreneurs are reluctant to invest in waste management innovations that are long-term and do not promise quick profits. As environmental issues began to come to the fore in Russia, the generation of new technologies accelerated noticeably.

With regard to the issue of the distribution of patents by type of waste management, the picture is quite homogeneous across all countries with slight differences (Fig. 2). In most countries, more than 40% of patents are for waste recovery, recycling and reuse. Practically in equal proportions, these are inventions related to the energy utilization of household and industrial waste - 12-13%. The share of patents related to the production of fertilizers from waste accounts for about 15%. The number of patents related to improving the collection of solid waste is 11-12% of the total number of all patents on waste management. Nearly a quarter of registered and granted patents are for other waste management methods not listed above.

As of 2018, according to the number of patents per capita in the studied countries, Canada, Japan and Korea occupy a stable leading position and have practically the same indicators.

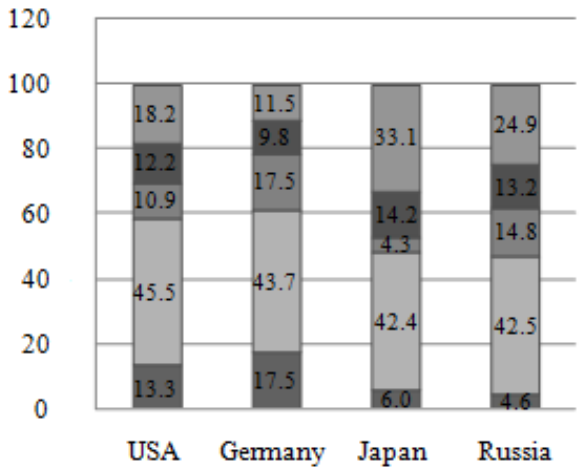

Fig. 2. The structure of the availability of patents in the areas of waste management.

Figure 3 shows the amounts of waste management patents and inventions (per 1 million people).

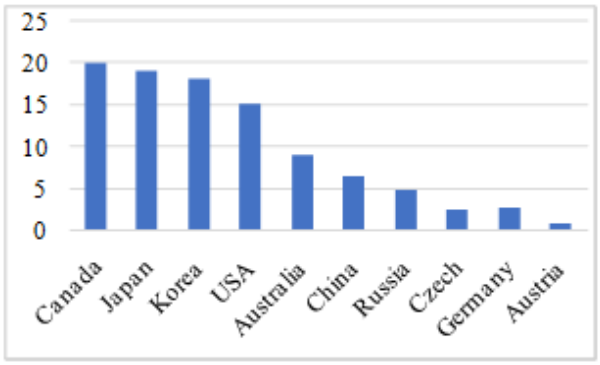

Fig. 3. The average number of patents per 1 million.

On the whole Russia occupies a satisfactory position in terms of the share of patents per capita, although it is not yet comparable with developed countries.

3 Results

The global tendencies of increasing the amount of waste pose a large number of questions for the scientific community to update and develop new technologies in the field of ecology.

Today all over the world the situation with the volume of waste becomes critical. Both the volume of waste and their diversity are growing. The only way to avoid getting bogged down in waste is to develop new methods of recycling. In this regard, the question arises about their effective processing, with the aim of returning to the production cycle. Researchers around the world are tackling this problem [17-20]. This can be judged by the indicators of R&D and patent activity. [21]

To determine the factors affecting patenting activity, we conducted a study in 35 countries of the European Union, OECD and Russia.

The data for 2018 on the patenting activity of countries in the field of technologies related to the

environment and ecology were used as the initial data (Table 3).

Table 3. Patent activity of countries [14].

Country	Environment-related technologies (waste management), number
Belgium	28
Czechia	14
Denmark	16
Germany (until 1990 former territory of the FRG)	183
Estonia	1
Ireland	4
Greece	8
Spain	35
France	134
Italy	92
Latvia	3
Lithuania	4
Luxembourg	2
Hungary	15
Netherlands	52
Austria	21
Poland	116
Portugal	13
Romania	17
Slovenia	3
Slovakia	10
Finland	44
Sweden	17
UnitedKingdom	114
Iceland	3
Norway	7
Switzerland	9
Turkey	16
Australia	543
Canada	576
Japan	1658
Korea	1706
UnitedStates	1570
China	22879
Russia	325

The leading countries in the development of technologies in the field of ecology are the United States, Japan, China, Korea, Germany. R&D spending (% of GDP) in these countries confirms their dominant position. In Korea - 4.81%, Austria - 3.18%, Japan - 3.26%, USA - 2.84%, Germany - 3.09%, Denmark - 3.06%, China - 2.19%. [22]

It is important to note that the leaders in terms of the number of people employed in R&D belong to China and the United States. China and the USA account for 37% and 11% of the total number of people employed in R&D, respectively. All other countries are far behind the leaders. So, Japan accounts for only 7.6% of all those employed in R&D, in Russia - 6.5%, in Germany - 6%.

In the article the analysis of patent activity across these countries was conducted by constructing a regression model. The main task of constructing a regression model is to identify a set of factors that impact the data. The significance of the indicators is checked by the Student's coefficient. Analyzing the innovative activity of the presented set of countries, it was suggested that inventive activity can be influenced by budget financing of R&D, investments in R&D from enterprises, the number of people employed in R&D, as well as the country's GDP. [23-25]

Thus, four hypotheses need to be tested:

H1 - the more allocations for R&D from the state, the wider the range of new research in the field of ecology;

H2 - the more investments in R&D from enterprises, the higher the number of developed technologies in the field of ecology;

H3 - the higher the rate of employment of the population in the field of R&D, the higher the inventive activity;

H4 - the higher the country's GDP, the more attention is paid to the development of new technologies in the field of ecology.

We have built a regression model and checked the significance of the obtained values by the Student's coefficient. The number of degrees of freedom is 34, the value of the Student's coefficient is 2.0322.

The resulting regression model is as follows:

$$y_1(x) = 0.1884\, x_1 + 0.001836\, x_2, \quad (1)$$

where x_1 is the financing of R&D by waste management enterprises, mln.

x_2 is the number of people employed in R&D, people.

The obtained values of the coefficients showed that the inventive activity is most influenced by the indicators X1 of R&D financing by waste management enterprises, as well as X2 the number of people employed in R&D.

The indicators X3, X4 of budgetary financing of R&D and GDP of countries entered into the model do not affect the resulting indicator.

4 Discussion

The analysis carried out according to the values of the studied countries shows that the level of innovative activity in the field of ecology, expressed in the patent activity of countries, is mainly influenced by the indicators of R&D funding from business, as well as the size of the population engaged in scientific research. This confirmed the hypothesis that enterprises are seriously concerned about the disposal of industrial waste, as well as the processing of their waste products.

Utilization and recycling of waste is a science-intensive process that requires the development of a research, technological base for inventive activity and confirmation of the obtained patent results. Due to this, the development of new technologies for waste disposal is one of the priority areas of activity for advanced and financially secured industrial enterprises.

The size of the R&D population also influences the level of inventive activity in countries. This indicates that an increase in the number of the educated population will bring the waste management policy to a new higher level.

The lack of a significant relationship with the GDP indicator is due to the economic structure of Western

countries, which is dominated by the service sector. To a greater extent, business's within the private sector are engaged in inventions and patents targeting ecology and waste management.

The predominance of the share of their added value was reflected to a greater extent on the indicator of the hypothesis H2.

5 Conclusions

Summing up the results of this review on the situation with patent activity in the field of waste management, it should be concluded that the relevance of patent activity in the world will remain for a long time.

The average annual growth rate of waste generation per capita in the countries of the Old World over the past 20 years is equal to two percent per year, and in Russia - 13%. Of course, this is significantly less than at the end of the last century. But the indications of the second decade of the 21st century in some countries are still quite high (Estonia 129.3%, Croatia 117.4%, Latvia 116.8%) [26].

According to research, patent activity in the field of waste management over the years, has become much more active. It was understood that waste is a promising raw material for the production of new types of products, a source of potential energy and an opportunity to obtain economic benefits. Countries need to scale up work towards introducing a circular economy. For some countries, it is important to organize a separate collection of waste, for others to improve the state policy in the field of environmental protection and to intensify innovative activities to implement the results of inventive activity. Patents are systemic tools to address these issues.

Environmental priorities for sustainable development pose a large number of tasks for the scientific community aimed at updating and developing new technologies in the field of ecology. Patents are economic resources that can transform knowledge into technology.

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