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Article

Estimation of global nanomedicine market : status, segment analysis, dynamics, competition and prospects

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ESTIMATION OF GLOBAL NANOMEDICINE MARKET: STATUS, SEGMENT ANALYSIS, DYNAMICS, COMPETITION AND PROSPECTS

The object of research is the state, segment analysis, dynamics, competition and prospects of the global nanomedicine market. The methods of searching and analyzing literary data, summarizing, systematizing and visualizing data using diagrams are used.

In 2020, health care was identified as the most commercial sector of the modern nanotechnology market with a share of capital investments of 19.5 %. The leadership of this field is due to the increased use of nanotechnology in the development of nanodiagnostics, nanosurgical robots, applications for cell repair, nanobiosensors, visualization and targeted drug delivery.

According to the analysis of the nanomedicine market, the structure of nanomaterials in 2022 was dominated by the segment of nanoparticles with a share of capital investments of 74 %, by the scope of application – the segment of drug delivery (25.1 %), by the method of action – the segment of treatment (23.8 %), by the scope of action – the segment of clinical oncology (32.4 %), by geographical regions – the segment of the North America region (26.4 %).

The main factors of the dynamics of the global market of nanomedicine are determined. This is an increase in the prevalence of chronic diseases; modern achievements in the development of nanomaterials and nanotechnologies; limited possibilities of the nanomedicine market; significant costs for scientific research, development of drugs and devices. As well as concerns about the safety of using nanomaterials and nanotechnologies; the potential toxicity and long-term effects of nanoparticle exposure on human health are under investigation.

Prospects for further scientific research in the field of nanomedicine are determined. This is the deepening of collaboration and cooperation of the world's scientists and manufacturers of medical nanoproducts; development of new technologies for obtaining nanoparticles, especially composites of organic and inorganic origin; creation of medicinal forms for external, internal and inhalation use. As well as the search for new nanopreparations and studying the mechanisms of their therapeutic action; research of toxicological, kinetic and dynamic effects of nanomaterials; establishment of all aspects of the interaction of nanostructures with the body and the environment. And a significant increase in the volume of scientific research on nanomedicine and nanophysiotherapy; an increase in government funding for research and development, which will open up attractive opportunities for the expansion of the global nanomedicine market.

Keywords: *nanomedicine, world market, market status, segment analysis, market dynamics, competition, market prospects.*

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1. Introduction

Nanotechnology operates with the study and application of structures having a size of 1–100 nm. Due to the unique physical and chemical properties of nanoparticles, nanotechnology is quickly finding application in various fields of medicine. The European Technology Platform on NanoMedicine: Nanotechnology for Health [1] defines nanomedicine as the application of nanotechnology for the purpose of health care, that is, the use of improved and new physical, chemical and biological properties of materials at the nanolevel. Nanomedicine has significant potential for the prevention, reliable early diagnosis and treatment of many diseases.

The document [1] also outlines three main areas of nanomedicine development:

1) diagnostics, including with visualization;
2) targeted delivery of drugs and their controlled release;
3) regenerative medicine.

Summarizing the materials of the sources [2–4] nanomedicine in a broad sense can be defined as:

– complex monitoring, control, construction, restoration, protection and improvement of all biological systems

at the molecular level using engineering nanodevices and nanostructures;
– sciences and technologies for diagnosis, treatment and prevention of diseases and traumatic injuries, reduction of pain, as well as for the protection and improvement of human health through the use of molecular tools and knowledge about the human body;
– application of molecular machine systems to solve medical problems using relevant knowledge to support and improve human health at the molecular level.

In studies [5, 6], nanomedicine is considered as a field of medicine that includes laboratories on a chip, targeted delivery of drugs to cells, nanorobots for the repair of damaged cells, molecular visualization, new antiviral and bactericidal substances, diagnosis of diseases using quantum labels, neuroelectronic interfaces, molecular biosensors, etc.

It is possible to summarize that the main directions of development of nanotechnology in modern medicine and pharmacy are:
– address delivery of medicines;
– creation of new medicines;
– antimicrobial coatings;
– molecular visualization, biodetection and labeling;
– nanocomposites for reconstructive medicine;
– nanomaterials for photodynamic therapy of cancer diseases.

The aim of research is to identify the patterns of development of the global nanomedicine market and to track modern trends and innovations in its development.

To achieve the aim, the following objectives should be performed:

1. To determine the potential demand and volume of the nanomedicine market in different countries.
2. To summarize information on the state and trends in the development of the global nanomedicine market.
3. To carry out a segmental analysis of the global nanomedicine market.
4. To monitor the dynamics and competition in the world market of nanomedicine.
5. To identify the key trends of the global nanomedicine market.

In a practical aspect, this will make it possible to predict trends in the further development of the global nanomedicine market and take them into account for the development of Ukraine's economy.

2. Materials and Methods

The object of research is the state, trends and structure of the global nanomedicine market.

The analysis of literary data [7–14] makes it possible to summarize the results of research by various scientists of the world regarding the use of nanomaterials, nanotechnologies and innovations in nanomedicine.

Today, the sixth technological system is considered as a paradigm of scientific and technological progress, which is characterized by the powerful development of engineering technologies based on the use of nanomaterials and nanotechnologies and the necessary level of knowledge and education [15]. Previously, we conducted a marketing study of the global [16, 17] and Ukrainian [17, 18] nanotechnology markets. It has been proven that the development of nanotechnology will determine the «face» of the 21st century. Data on the main trends and characteristics of markets, positive and negative factors of influence, prospective directions of research, the existing level of commercialization, and further development prospects are given. In part, works [15–18] cover the issue of the use of nanotechnology in medicine. But taking into account the significant potential and prospects of nanomedicine, the need to pay special attention to this topic is clear.

Information sources provide various data on the volume of the global nanomedicine market, forecasts of its changes and cumulative average annual growth rates (CAGR). The reason for the discrepancies is a different approach to market segment analysis (different number of researched segments), which does not always allow covering the entire market volume, as well as different research terms and forecasting periods. But common to all data is the confirmation of a significant increase in capital investments in this area of medical development.

The following scientific methods were used in the study:
– method of searching for literary data on the researched topic;
– method of analysis of literary sources;
– comparative analysis of various methodological approaches;
– content analysis of documents;
– method of systematization and classification when conducting research on the achievements of modern science in the field of nanomedicine.

3. Results and Discussion

3.1. Analysis of the nanotechnology market by industry. The analysis of the nanotechnology market by industry was carried out on the basis of research data [19] for the following segments: electronics, health care, production, energy, road transport, aerospace and defense industry, food industry, agriculture (Fig. 1). The dominant position in 2022 belonged to the healthcare sector with a share of capital investments of 19.5 %. The second position is in the field of electronics (16.6 %), the third is in the aerospace and defense industry (15.4 %).

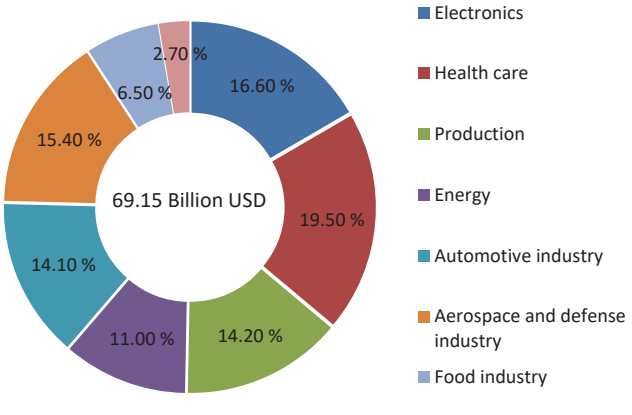

Fig. 1. Segment analysis of the global nanotechnology market by industry in 2022 (built on the basis of data [19])

Healthcare leadership is driven by the increasing use of nanotechnology in the development of nanodiagnostics, nanosurgical robots, cell repair applications, nanobiosensors, visualization, and targeted drug delivery. The increased prevalence of numerous chronic diseases worldwide and the increased application of surgical procedures to patients are expected to increase the demand for nanomedical technologies for the production of various surgical instruments

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and equipment. These factors will increase the demand for products in the medical segment during the forecast period.

But the largest growth rates during the forecast period (2022–2030) will be observed in the aerospace and defense industries. The creation and improvement of light and strong materials, improved sensors, energy storage and efficient propulsion systems will provide better performance, increased durability, innovative solutions, the development of more compact and powerful devices in the aerospace and defense sectors.

According to research [19], the dominance of the health care segment in 2022 was also observed in the nanotechnology market of the leading «player» – the United States of America, but with minor changes in the positions and shares of other segments (Fig. 2).

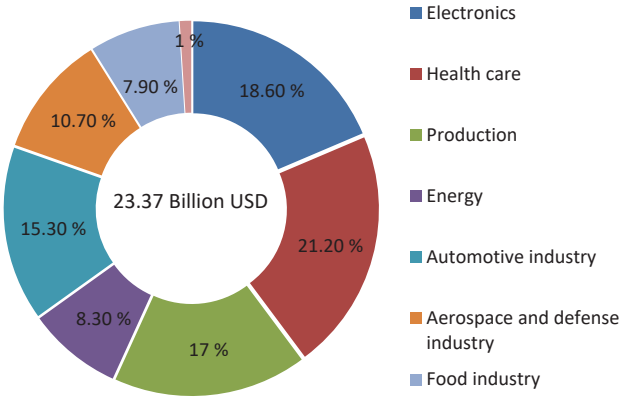

Fig. 2. Segment analysis of the nanotechnology market by industry in the USA in 2022 (built on the basis of data [19])

3.2. General characteristics of the global nanomedicine market. According to data [20] in 2022, the global nanomedical market was estimated at 139 billion USD with an expected growth in 2032 to a mark of 358. This growth should be supported by a 10.2 % CAGR. According to this source, the main features of the nanomedicine market are defined (Table 1).

In [21], the forecasted dynamics of the world market of nanomedicine in the period 2021–2032 are given, with an estimated value of 30–40 billion USD (Fig. 3).

According to another source [22], the volume of the global nanomedicine market in 2021 was estimated at 156.2 billion USD, growing to 174.2 billion in 2022. In 2030, this volume is expected to grow to 416.1 billion with a CAGR of 9.8 % over the forecast period (2023–2030).

The main purpose of the nanomedicine market is to develop innovative solutions that can solve the problems of unsolved medical needs and improve the treatment of patients. The use of nanomaterials and nanotechnologies in medicine can lead to a number of advantages over traditional medical approaches:

– improvement of drug delivery;
– improvement of bioavailability;
– reduction of side effects;
– improvement of target therapy.

The use of nanotechnology in medicine will make it possible to give it a more personalized character, adapted to the individual needs of the patient. The following are the main drivers of the growth of the global nanomedicine market:

– development of nanotechnology has led to the emergence of new tools and methods for precise manipulation and control of medical processes at the nanolevel;
– discovery of the possibility of using modern advances in nanotechnology for new medical applications;
– unexpected rates of expansion of application and commercialization of nanomedical products and processes.

Table 1

The main features of the world market of nanomedicine and their content

Market feature	Content of market features
Market growth	The nanomedicine market, valued at 139 billion USD in 2022, is projected to reach 358 billion USD by 2032, with a CAGR of 10.2 %
Dominance of the nanoparticle segment	Nanoparticles accounted for a significant revenue share of 74 % in 2022, projected to be the fastest growing segment due to their diverse applications
Leadership of the clinical oncology segment	In 2022, clinical oncology led the way, accounting for the largest market share due to the global increase in the prevalence of cancer
Leadership in the share of drug delivery in total revenue	Drug delivery segment to account for largest revenue share in 2022 due to increased disease awareness and application of nanomedicine
Growth of the therapeutic segment	The therapeutic segment is predicted to grow significantly due to technological advances in nanotherapy
Market factors	Increased prevalence of chronic diseases is driving market growth, especially in addressing the mismatch between available treatments and patient needs
Cost limitations	High cost of manufacturing, research and development of nanodrugs and nanodevices pose challenges, affecting the potential growth of the market during the forecast period
Pharmaceutical possibilities	The active participation of pharmaceutical companies in therapy based on nanoscience opens up significant opportunities for the development of the nanomedical industry
Influence of state funding	Increasing government funding, especially in North America, is accelerating nanomedicine research, contributing to market expansion
Regional dynamics	North America dominated with a revenue share of 46 % in 2022. Asia Pacific is expected to expand significantly due to increased public engagement

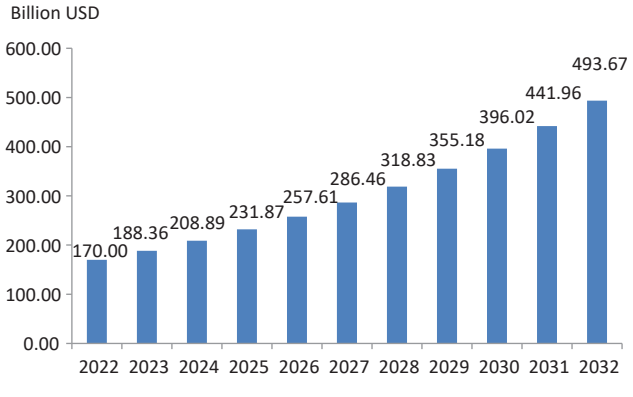

Fig. 3. Dynamics of the global nanomedicine market (built on the basis of data [21])

The nanomedicine market also faces certain restraining factors. One of the key problems is the scientific complexity, complexity and high cost of nanotechnology research. At the research and preclinical stages of nanomedicine, promising results are often achieved, but their transformation into cost-effective commercial products requires considerable effort and time. The nanomedicine market opens

up significant opportunities for innovation. Thanks to the unprecedented pace of research in the field of nanotechnology, there is a huge potential for the development of new therapeutic approaches and diagnostics. Nanomedical drugs and technologies are promising for targeted drug delivery systems, personalized medicine, and non-invasive visualization techniques. The world market of nanomedicine in the future will be able to fundamentally change the health care industry, using the potential of nanotechnology to improve diagnostics, targeted therapy and personalized medicine.

3.3. Segment analysis of the global nanomedicine market. The analysis of the world market of nanomedicine was carried out according to the following segments:

– structure of nanomaterials;
– scope of application – therapy, in vitro diagnostics, drug delivery, in vivo visualization and implantation;
– method of action – treatment and therapy;
– scope – clinical oncology, infectious diseases, clinical cardiology, orthopedics, etc.;
– geographical regions – North America, Europe, Asia-Pacific region, Middle East and Africa, Latin America.

3.3.1. Analysis of the nanomedicine market by the structure of nanomaterials. Based on research data [20], it is possible to segment the nanomedicine market (by the structure of nanomaterials) into nanoparticles, nanotubes, nanocapsules, and nanodevices. Among these segments, the nanoparticle segment dominated the market with a capital investment share of 74 % in 2022 (Table 2). The growth of this segment is projected to continue at the fastest rate during the forecast period of 2022 to 2032. This is mainly due to the advantages of chemically different nanoparticles. There are also other reasons for the growth of the segment. One of them is the increased use of metals and metal oxide particles in photodynamic therapy for the treatment of onco and infectious diseases, another is the ability of nanoparticles to perform a variety of tasks due to their ability to bind to chemical moieties in various framework forms. In nanotechnology, nanoparticles are used for selective binding by attaching them to ligands of cell receptors. This is also driving the demand for nanoparticles.

According to forecasts, the shares of capital investments of segments of nanotubes, nanocapsules and nanodevices to the general market will not change significantly in the forecast period and will be within the range of 8.0–9.6 % (Table 2).

Using the research data [23], it is also possible to carry out a segmental analysis of the global nanomedicine market by similar segments (Fig. 4). The dominant position of the nanoparticle segment is maintained with a similar percentage of capital investments (74.3 % vs. 74.0 %). But the sequence of the remaining segments is completely different: nanotubes (12.0 %), nanodevices (9.4 %), nanocapsules (4.3 %).

Table 2

Segmentation of the global nanomedicine market by the structure of nanomaterials

Year	Total market volume, billion USD	Share of capital investments of the segment, % (volume of the segment, billion USD)			
		nanoparticles	nanodevices	nanocapsules	nanotubes
2022	139	74.0 (102.9)	10.4 (14.4)	8.6 (12.0)	7.0 (9.7)
2032	358	73.7 (263.8)	8.7 (31.3)	9.6 (34.3)	8.0 (28.6)

The nanotubes segment is expected to grow at a significant CAGR of 10.9 % from 2023 to 2030. This variety of nanomaterials can perform a variety of tasks due to their ability to bind to chemical moieties in the form of scaffolds. For example, the incorporation of carbon nanotubes into scaffolds for tissue engineering can improve their properties and lead to improved tissue regeneration.

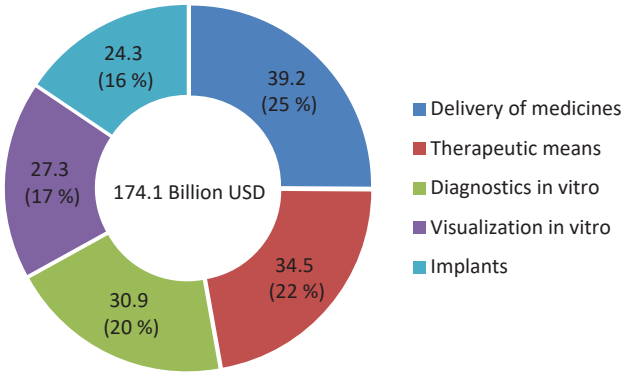

Fig. 4. Segment analysis of the world market of nanomedicine by the structure of nanomaterials (built on the basis of data [23])

According to research data [24], a segmental analysis of the world market of nanomedicine can be obtained according to a slightly different classification of nanoparticles, with the separation of inorganic and polymeric ones; nanocrystals; liposomes and micelles (Fig. 5). Dominant positions belong to segments of polymer nanoparticles and nanocrystals in the share of capital investments, which account for 29 % of the total nanoparticle market. Liposome segments, inorganic nanoparticles, and micelles account for 20.16 and 6 %, respectively.

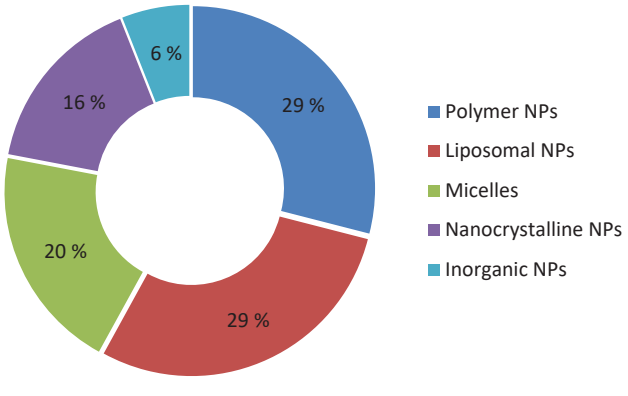

Fig. 5. Segment analysis of the world market of nanomedicine by the structure of nanoparticles (built on the basis of data [24])

3.3.2. Analysis of the nanomedicine market by scope of application. According to the segmental analysis of the global nanomedicine market by field of application (Fig. 6), performed using data [22], the drug delivery segment was dominant in 2021 (25.1 %). The shares of the remaining segments were in the range of 17.5 % (implantation) – 22.1 % (therapy). In 2022, the share of the drug delivery segment increased to 34.1 %. This is the most popular field of application of nanotechnology in medicine: its share in the total market volume in 2020 accounted for 78 % of sales and 58 % of patent applications

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worldwide, revenue from the manufacture and sale of drug delivery systems exceeded 170 billion USD [8].

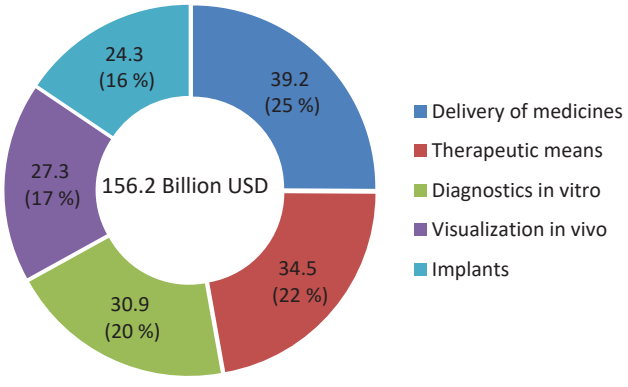

Fig. 6. Segment analysis of the nanomedicine market by fields of application (built on the basis of data [22])

This leading position of the drug delivery segment can be explained by the growing prevalence of chronic and infectious diseases, which revealed an urgent need for effective drug delivery systems. Another reason was the increase in public awareness of the potential of nanotechnology. Progress in this segment is also due to the successful results of research by scientists and pharmaceutical companies in this direction.

The advantages of the drug delivery system can undoubtedly be the following:

– delivery of drugs directly to diseased cells, without affecting healthy cells and minimizing the side effects of drugs;
– increasing the bioavailability of drugs by increasing their effectiveness, and the accuracy of delivery and dosage, reducing toxicity for the body, using safe delivery;
– reducing the time of drug delivery by increasing the speed of movement through the body due to the various design and structure of nanoparticles;
– increasing the effectiveness of drug treatment by creating drug carriers for transferring several drugs at the same time;
– reducing side effects and increasing the effectiveness of drugs by creating the possibility of programming the release of drugs at certain time intervals with the necessary duration in time;
– increasing the effectiveness of disease treatment by creating drug delivery systems that are better able to penetrate cell membranes;
– reducing the required number of drugs due to their increased effectiveness.

It is expected that in the period 2023–2030, the therapeutic segment will also grow at a rapid pace with a CAGR of 12.79 % [22]. This segment covers various nanomedical products used for therapeutic purposes and includes drugs, devices and drug delivery systems.

The availability and availability of a wide range of nanotherapeutics for the treatment of various diseases will contribute to the growth of this segment. In addition, technological progress has contributed to the development of nanotherapeutic drugs capable of effectively overcoming biological barriers, allowing targeted and precise treatment. It is assumed that the mentioned circumstances and achievements will contribute to the development of the nanotherapy market in the coming years.

The segmental analysis of the global nanomedicine market by scope of application for the period 2022–2030 (Table 3) performed using the data [22] practically coincides with the results of the analysis performed according to the data [22] for 2021 (Fig. 6). In addition, it allows to predict some changes in the shares of individual segments. A decrease in the share of the drug delivery segment and an increase in the share of the in vivo visualization and implantation segments are expected. Shares of segments of therapy and in vitro diagnostics practically do not change.

In contrast to the performed segmental analysis based on the scope of application based on the data [22] (Table 3), a similar analysis based on the data [20] can be performed not on five, but on six segments: therapy, active implantation, in vivo visualization, in vitro diagnostics, drug delivery and implantation (Fig. 7).

As in the previous analysis, the drug delivery segment dominated the global nanomedicine market in 2022 (24.9 %) and accounted for the largest share of revenue. This significant share of the market segment was determined by the increase in morbidity, including oncological diseases, and the increase in people's awareness of the possibilities of nanomedicine. Differences in the shares of the remaining segments are due to the separate consideration of active implantation (16.4 %) and implantation (10.0 %). Similarly, the therapeutics segment is expected to witness significant growth during the forecast period due to the development and deployment of nanoproducts (devices, drugs, and drug delivery systems) suitable for the treatment of various diseases. Advances in technology are expected to provide the improvement of nanotherapeutics with improved characteristics of overcoming biological barriers.

In the study [25], the vaccination segment was additionally taken into account as the basis for the segmentation of the nanomedicine market by scope of application (Fig. 8). Despite a different approach to the selection of segments, the leading position in 2022 will be retained by the drug delivery segment (35.9 %). But according to this analysis, its share increases by about 10 %. The used vaccination segment is in second place (21.9 %). In the future, the sequence of the location of the segments is as follows: in vitro diagnostics (19.2 %), in vivo visualization (15.2 %), implantation (6.4 %), other applications (1.4 %).

Table 3

Segmentation of the world market of nanomedicine by field of application

Year	Total market volume, billion USD	Share of capital investments of the segment, % (volume of the segment, billion USD)				
		Delivery of medicines	Therapy	Diagnostics in vitro	Visualization in vivo	Implantation
2022	174.2	25.5 (44.4)	21.9 (38.1)	20.4 (35.5)	17.9 (31.2)	14.3 (25.0)
2030	416.1	22.7 (94.5)	21.2 (88.2)	20.7 (86.1)	18.4 (76.6)	17.0 (70.7)

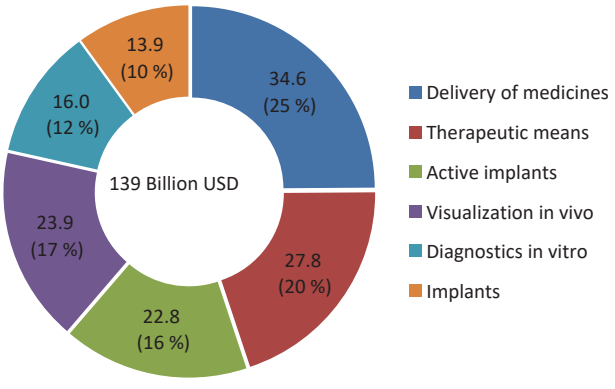

Fig. 7. Segment analysis of the nanomedicine market by areas of application (built on the basis of data [20])

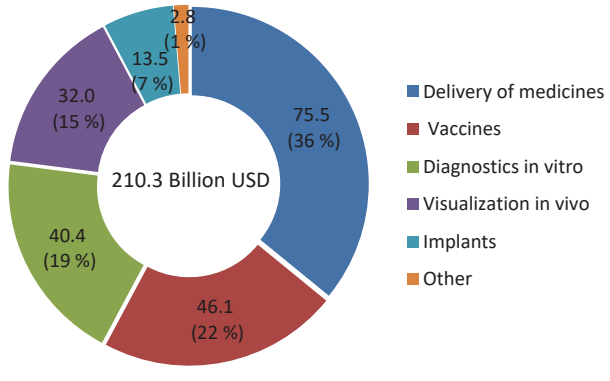

Fig. 8. Segmentation of the global nanomedicine market by expanded scope of application (built on the basis of data [25])

Research data [23] allow to compare the growth rates of the volume of capital investments in the application segments of the global nanomedicine market in the forecast period of 2020–2030. The highest growth rates are expected for the segments of regenerative medicine (increase by 2.64 times) and vaccination (by 2.50 times). The growth of the diagnostic, implantation, and drug delivery segments will occur at the same rates in the range of 2.22–2.34 times and will maintain dominant positions.

3.3.3. Analysis of the nanomedicine market by mode of action. A segmental analysis of the global market of nanomedicine by mode of action can be carried out based on the results of research [25] regarding the areas of treatment and diagnostics (Table 4). Over the forecast period, the share of the diagnostic segment is expected to increase from 24.6 to 34.9 % and the share of the treatment segment to decrease from 75.4 to 65.1 %.

Table 4

Segmentation of the global nanomedicine market by mode of action

Year	Total volume, billion USD	Share of capital investments of the segment, % (volume of the segment, billion USD)	
		Treatment	Diagnostics
2021	187.9	75.4 (141.7)	24.6 (46.2)
2022	210.3	73.8 (155.2)	26.2 (55.1)
2032	597.8	65.1 (389.2)	34.9 (208.6)

3.3.4. Analysis of the nanomedicine market by scope. Analysis of the global nanomedicine market by scope includes segments of clinical oncology, orthopedics, clinical cardiology, infectious diseases, etc. The clinical oncology segment accounted for the largest market share in 2022 (32.4 %) and is expected to grow potentially during the forecast period [22]. This dominance is explained by the growing prevalence of cancer worldwide, the continuous search for a wide range of drugs for their treatment. These drugs are currently at the stage of clinical development, which requires a significant increase in the amount of scientific research and innovative solutions for clinical oncology. The research of a significant number of nanoproducts for the treatment of cancer diseases in the clinical stages of development and the successful results of the application of therapeutic particles and devices contributed to the growth of this segment. Greater efficiency and fewer side effects in the treatment of cancer diseases define nanomedicine as an effective method of treatment. Clinical oncology in the nanomedicine industry encompasses various active and passive methods of targeting cancer cells, which will contribute to the further growth prospects of the respective segment in the market.

According to preliminary forecasts, the segment of infectious diseases will grow at a rapid pace, with a forecasted CAGR of 12.3 % by 2030 [22]. This growth is due to the urgency of developing effective, fast and cost-effective methods of treating infectious diseases. Nanomedicine is becoming a promising method of treatment due to its high targeting efficiency and reduction of side effects. The unique properties of nanomedicine enable the treatment of a wide range of infectious diseases.

3.3.5. Analysis of the nanomedicine market by geographic regions. Based on region, the global nanomedicine market is segmented into North America, Europe, Asia Pacific, Latin America, and the Middle East and Africa. According to the segment analysis of the global nanomedicine market by geographic regions (Fig. 9), performed using data from [22], in 2022, the dominant region in the market was North America, which accounted for 26.4 % of all capital investments of the total market volume. At the same time, the United States of America (57.9 %) and Canada (42.1 %) account for almost 100 % of capital investments in the North America region. Leading positions also belonged to the Asia-Pacific region (22.0 %) and Europe (19.8 %). The countries of Latin America and the Middle East and Africa accounted for 15.0 % and 16.8 %, respectively.

The North American region is expected to maintain its leading position throughout the forecast period (23.4 %) (Fig. 10). The region's leadership can be explained by the presence and expansion of partnerships between well-known enterprises and successful start-up companies in the field of nanomedicine, and the increase in alliances between enterprises in this field and newly created nanomedicine companies. In addition, research institutions and enterprises of the region receive strong support from the government. This is also facilitated by increased investment in research, development and implementation of the achievements of nanoscience in medicine. The expansion of the nanomedicine market is also influenced by the growing demand for the prevention of life-threatening diseases and the increase in research funding in the United States of America. The North American region is also home to a significant number of manufacturing firms that are actively engaged in strategic activities in the field of nanomedicine.

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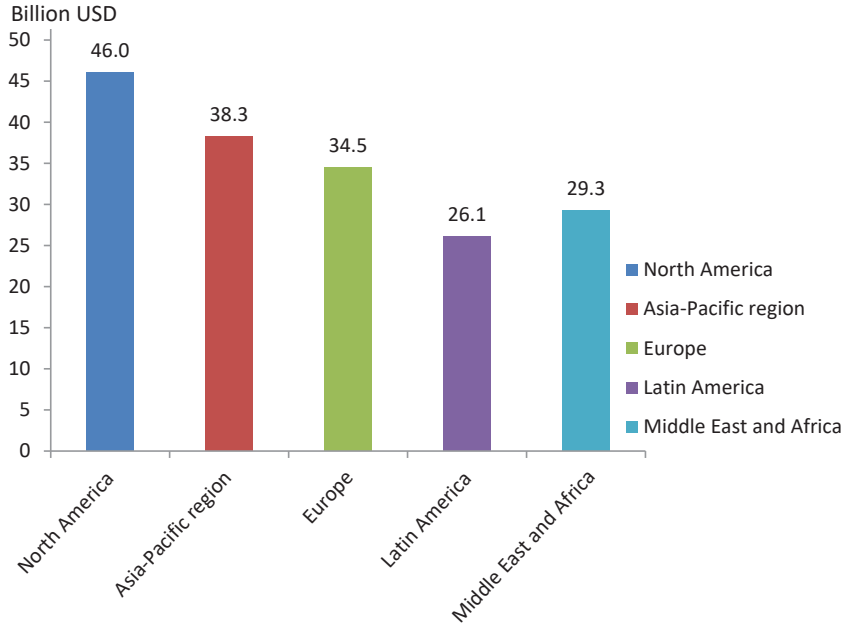

Fig. 9. Segmentation of the global nanomedicine market by geographic regions in 2022 (built on the basis of data [22])

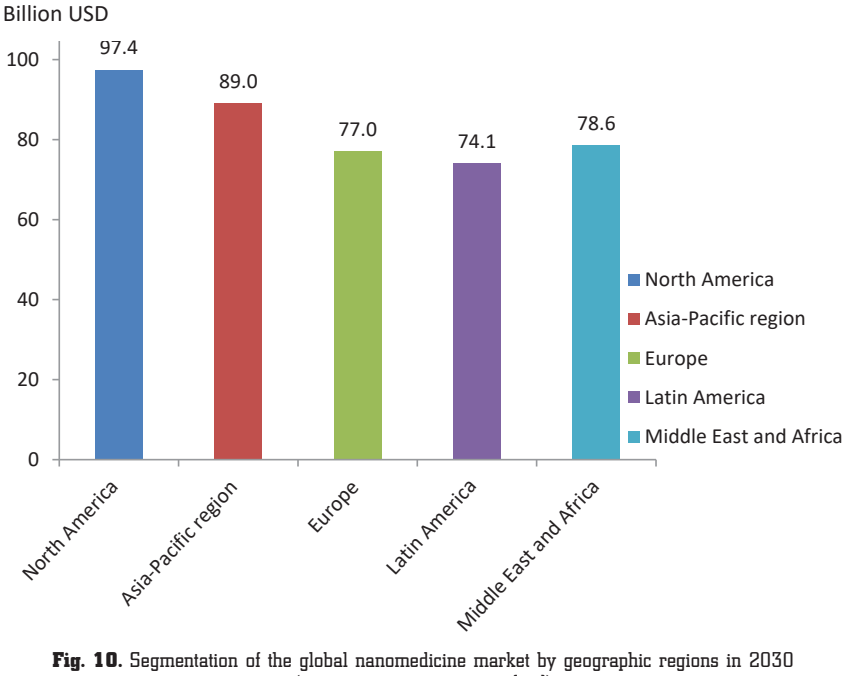

Fig. 10. Segmentation of the global nanomedicine market by geographic regions in 2030 (built on the basis of data [22])

According to preliminary forecasts, the fastest growth rate of 14.1 % for the period from 2023 to 2030 is expected in the market of the Asia-Pacific region with a projected share of 21.4 % [22]. These rates can be explained by increasing the awareness of the population of the region regarding the possibilities of nanomedicine and the active involvement of the public in various activities related to nanosciences and nanotechnologies. According to forecasts, the shares of Latin America (17.8 %) and the Middle East and Africa (18.9 %) will increase. Of course, this may lead to a decrease in the share of the European market (18.5 %).

According to the results of the performed segmental analysis of the global nanomedicine market by geographic regions using data [21], the dominant region on the market in 2022 is also North America (Fig. 11). But the share of capital investments in the region according to this analysis is somewhat smaller and amounts to 34 %. There are also minor differences by individual regions compared to the analysis performed on the basis of data [22] (Fig. 9, 10).

According to the results of the study [19], North America also has the largest share of the global nanotechnology market. Asia Pacific is expected to witness rapid growth during the forecast period (2023–2030) owing to increasing applications and investments in nanotechnology. In addition, increasing adoption of the technology in medical diagnostics and government funding for research and development to create nanodevices is expected to drive market growth in the coming years. Europe is also expected to exhibit a steady growth rate during the forecast period. The development of industry in Europe and the higher level of introduction of new and advanced technologies in production facilities have contributed to the growth of the market. European governments have played a key role in the introduction of new nanotechnologies in the industrial sector, contributing to the growth of the market. Rising disposable incomes and rising living standards have increased demand for sensors, advanced electronics, and photonic devices for medical applications. Availability of innovative healthcare infrastructure and improved access to advanced healthcare facilities are contributing to further market growth due to increasing demand for medical devices in the healthcare sector.

In addition, the Middle East and Africa market is expected to witness significant growth in the coming years due to increased investment and government funding for digitization.

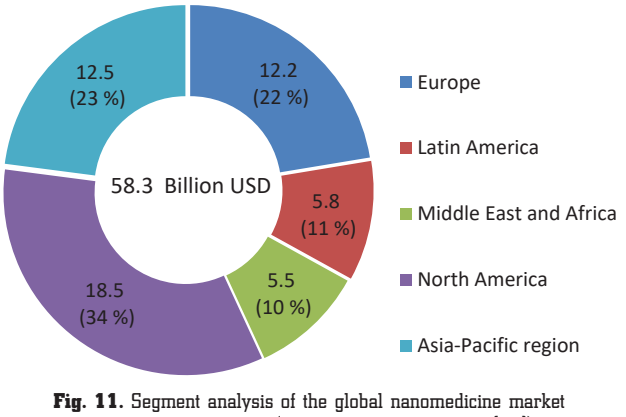

Fig. 11. Segment analysis of the global nanomedicine market by geographic regions (built on the basis of data [21])

3.4. Dynamics and competition in the world market of nanomedicine. The analysis of literary data [4–12, 23, 24] makes it possible to determine the main factors influencing the dynamics of the global nanomedicine market:

– increasing prevalence of chronic diseases – cancer, cardiovascular diseases and diabetes are the main drivers of the nanomedicine market (in this case, nanomedicine offers targeted and personalized therapy that can improve treatment outcomes and the patient's condition);
– modern achievements in the development of nanomaterials and nanotechnologies – constant progress in nanotechnologies has opened the way for innovative nanomedical solutions (improvement of drug delivery systems, improvement of imaging systems and the development of nano-sized diagnostic tools have expanded the possibilities for their use in nanomedicine, stimulating market growth);
– limited possibilities of the nanomedicine market;
– significant costs for conducting scientific research, development of drugs and devices, their implementation – the development and commercialization of nanomedical products requires the involvement of significant funds for research and development (complex production processes and regulatory requirements determine the high cost of production of nanomedical products on the market, which may prevent widespread implementation);
– concerns about the safety of the use of nanomaterials and nanotechnologies – ensuring the safety and biocompatibility of nanomedical products is crucial for their successful use;
– potential toxicity and long-term effects of nanoparticles on human health are under study – resolving safety issues and obtaining regulatory approvals creates challenges for market growth.

According to research results [21], the increase in the global burden of chronic and infectious diseases is the main reason for the growth of the global nanomedicine market. According to the World Health Organization, cancer is the second leading cause of death in the world, responsible for more than 9.5 million deaths in 2018. The ability of nanomedicine to control the activity of lymphoid and myeloid cells, as well as to improve immunity against cancer diseases and the effectiveness of immunotherapy will facilitate its use in the fight against such diseases.

Nanopreparations are widely used for the treatment of chronic diseases (diabetes, cardiovascular diseases, dementia, cancer and others). Such use promotes rapid metabolism of drugs in the body. Hence, the increasing prevalence of chronic diseases is expected to fuel the growth of the nanomedicine market. Although the healthcare and medical sectors have experienced incredible development in recent years, with the introduction of advanced treatments and products such as non-invasive surgical instruments, advanced medical sensors and portable imaging devices, there remains a large gap between available treatments and needs patients Advances in nanomedicine help fill this gap. Nanodrugs are promising for drug delivery to the target site in the correct proportion and with realistic delivery rates. The use of nanomedicines is expected to meet the requirements for the treatment of complex diseases, potentially contributing to the growth of the global nanomedicine market.

Of course, in addition to the factors contributing to the growth of the global nanomedicine market, there are also certain limitations regarding the possibility of using nanomaterials and nanotechnologies in medicine. Significant costs associated with nanomedicine manufacturing and nanomedicine research are hindering market growth. There is growing concern about the manufacturing and R&D costs for key players in the nanomedicine market and the market price for the end user. Research and development require a lot of resources, which raises concerns about obtaining funds. This significant investment is expected to be reaped by the innovator with significant returns, resulting in increased product value for the end user. As a result, the high cost associated with nanomedicine is likely to hinder the growth of the market during the forecast period.

The global nanomedicine market is highly competitive and brings together pharmaceutical companies, biotech firms, research institutions and emerging nanomedicine startups. These «players» of the market take an active part in research and development, strategic cooperation, introduction of new products to gain a competitive advantage. The world market of nanomedicine is characterized by sharp and tough competition, the need for constant research and research, and the rapid implementation of developments. With the growing adoption of nanotechnology in the health care industry, competition is becoming even more intense.

New key players in the global nanomedicine market are highly focused on implementing various growth strategies to develop their portfolios and expand their presence in foreign markets. Several nanomedical companies are focusing on expanding existing operations and increasing R&D spending. Some key players are currently focusing on various marketing strategies, such as spreading awareness about nanomedicine, which is driving the growth of targeted products.

The leading «players» in the nanomedicine market include the following top companies from the USA, Switzerland, Germany, Great Britain, Japan, France and Israel:

– USA – Pfizer Inc.; Johnson&Johnson; Merck&Co. Inc.; Abbott Laboratories; Gilead Sciences Inc.; Celgene Corporation; Amgen Inc.; Eli Lilly and Company; Bristol-Myers Squibb Company; Biogen Inc.;
– Switzerland – Novartis International AG; Roche Holding AG;
– Germany – Boehringer Ingelheim International GmbH; Bayer AG;
– Great Britain – Glaxo Smith Kline plc; Astra Zeneca plc;
– Japan – Astellas Pharma Inc.; Takeda Pharmaceutical Company Limited;
– France – Sanofi S.A.;
– Israel – Teva Pharmaceutical Industries Ltd.

3.5. Key trends in the global nanomedicine market. Key trends in the development of the global nanomedicine market are considered to be: personalized medicine, and the combination of various treatment methods. Personalized medicine is nanomedicine that allows for personalized approaches to treatment, drug delivery, or therapy based on a person's individual needs. The trend towards personalized medicine promotes the introduction of nanomedicine, as the latter allows targeted and individualized treatment.

A growing trend in nanomedicine is the combination of methods such as immunotherapy and gene therapy. Combining different therapeutic approaches can increase the effectiveness of treatment, overcome drug resistance and provide a synergistic effect, opening new opportunities for nanomedical programs.

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Until now, most of the research in nanomedicine has been aimed at improving the action of existing medical drugs and improving their delivery systems. Recently, new areas of research have appeared. Summarizing the results of research [4–12, 26–33] made it possible to single out the most interesting and promising innovative directions for the development of nanomedicine with the implementation of the following tasks:

– monitoring and control of delivery, distribution and use of drugs – replacing passive targeting of components with active targeting;
– development and delivery of vaccines – use of prefabricated nanoplatforms capable of modification and various techniques for transporting nanovaccines;
– regenerative medicine – prosthetics and restoration of tissues and organs, protection of transplanted organs from harmful substances;
– nanobiosensors – increasing the level of sensitivity for the detection of chemical substances, as well as the recognition, capture and concentration of biomolecules;
– diagnostics – probing of cell movements and detection of molecular changes and/or individual molecules, conducting diagnostics of tissues and organs in-vivo in real time;
– nanotoxicology – the study of the reaction of living organisms to nanopreparations and the development of more effective and less toxic nanomedicines and treatment schemes, the study of the toxicity of nanoparticle waste and their impact on the environment;
– nanophytopharmaceutics – integration of the principles of nanotechnology into the process of production of effective phytomedicines to overcome the existing shortcomings of traditional phytopreparations and to maximize the potential of phytomolecules;
– «green» synthesis – research into the possibilities of synthesis of metal nanoparticles using plant extracts and microorganisms and further use of microorganisms as «nanofactories»;
– nanorobotics – designing and manufacturing nano-sized biosystems, starting processes, manipulation, movement, signaling, data collection and information processing, performing vital functions for the body.

Analysis of data from the literature [27–33] and the results of our own research make it possible to summarize the state of affairs and determine the prospects for further scientific research in the field of nanomedicine:

– deepening cooperation and collaboration of world scientists and manufacturers of medical nanoproducts;
– development of new technologies for obtaining nanoparticles, especially composites of organic and inorganic origin;
– creation of medicinal forms for external, internal and inhalation use;
– searching for new nanopreparations and studying the mechanisms of their therapeutic action;
– research of toxicological, kinetic and dynamic effects of nanomaterials;
– establishment of all aspects of the interaction of nanostructures with the body and the environment;
– significant increase in the volume of scientific research on nanomedicine and nanophysiotherapy;
– increase in state funding of research and development will open up attractive opportunities for the expansion of the global nanomedicine market.

In order to use these perspectives, it is necessary to create appropriate opportunities and conditions:

– active participation of pharmaceutical companies in the development of new treatment methods based on nanotechnology;
– improvement and expansion of the use of nanotechnology in early diagnosis and prevention of acute and chronic diseases and disorders, their prevention;
– expanding the field of nanomedicine in the healthcare sector;
– active participation of large pharmaceutical companies in the production of advanced drugs based on nanoscience.

Today, there is an increased interest of the public in the problems of nanomedicine with the emergence of many social, humanistic, moral and ethical issues. The novelty and lack of knowledge of nanomaterials and nanotechnologies requires the study of potential uses and possible risks from the point of view of safety, toxicity, consequences for human health and the environment, and general ethical and political issues [34–38]. The specific ethical aspects of nanomedicine raise complex questions for society that cause concern:

– creation of complex conditions of control and tracking of consequences due to the invisible nature of nanomedical processes;
– extreme difficulty of forecasting, prompt detection and response to potential dangers due to the rapid development of nanoscience and nanoproduction;
– emergence of a potential threat to human rights in connection with the possibility of applying the achievements of nanomedicine for security and defense;
– potential impact on countries and societies that do not participate in nanotechnological developments;
– potential growth of inequality between developed and developing countries.

3.6. Discussion

Strengths. In this work, the systematization and analysis of literature data in the field of nanomedicine was carried out at the same time. The state of the world market of nanomedicine was considered, a segmental analysis of the market was performed, dynamics, competition and prospects for its development were studied. The combination of these data makes it possible to reveal the current state and prospects of the world market of nanomedicine in a more reasonable way.

Weaknesses. Virtually no reports on this topic are publicly available.

Opportunities. Further research will be aimed at using the results of the analysis of the world market of nanomedicine carried out in this work for the formation of the corresponding Ukrainian market. Achievements in the field of nanomedicine are the result of scientific and practical research in many countries. Therefore, the experience of these countries is very useful for the development of their own nanomedicine.

Threats. The rapid development of nanomedicine makes certain corrections in various aspects of the research of the world market of nanomedicine.

4. Conclusions

It has been determined that the main areas of development of nanomedicine are diagnostics; targeted delivery of

drugs and their controlled release; regenerative medicine, and the main directions of development of nanotechnology in modern medicine and pharmacy:

– address delivery of medicines;
– creation of new medicines;
– antimicrobial coatings;
– molecular visualization, biodetection and labeling;
– nanocomposites for reconstructive medicine;
– nanomaterials for photodynamic therapy of cancer diseases.

The analysis of the nanotechnology market by industry for 2022 determined the dominant position of the healthcare industry with a share of capital investments of 19.5 %. Healthcare leadership is driven by the increasing use of nanotechnology in the development of nanodiagnostics, nanosurgical robots, cell repair applications, nanobiosensors, imaging, and targeted drug delivery.

The nanomedicine market is estimated at 139–174 billion USD in 2022 by various sources and is projected to reach 358–416 billion USD by 2032 with a CAGR of 9.8–10.2 %. The main driving factors of the growth of the global nanomedicine market are:

– development of nanotechnology, which led to the emergence of new tools and methods for precise manipulation and control of medical processes at the nanolevel;
– discovery of the possibility of using modern advances in nanotechnology for new medical applications;
– unexpected rates of expansion of application and commercialization of nanomedical products and processes.

According to the carried-out segmentation of the nanomedicine market by the structure of nanomaterials, the segment of nanoparticles dominated the market with a share of capital investments of 74 % in 2022. This is due to the advantages of nanoparticles of different chemical nature, the increase in the use of metals and metal oxide particles in photodynamic therapy for the treatment of onco and infectious diseases, the ability of nanoparticles to perform various tasks due to their ability to bind to chemical moieties in various framework forms.

The segment analysis of the global nanomedicine market by field of application revealed that the drug delivery segment was dominant in 2021 (25.1 %). The shares of the remaining segments were in the range of 17.5 % (implantation) – 22.1 % (therapy). The share of the drug delivery segment in the total market in 2020 accounted for 78 % of sales and 58 % of patent applications worldwide, revenue from the manufacture and sale of drug delivery systems exceeded 170 billion USD.

A segmental analysis of the world market of nanomedicine by mode of action in relation to the fields of treatment and diagnostics showed that over the forecast period of 2022–2032, the share of the diagnostics segment is expected to grow from 24.6 to 34.9 % and the share of the treatment segment to decrease from 75.4 to 65 % and a decrease in the share of the treatment segment 1 %.

Analysis of the global nanomedicine market by scope identified that the clinical oncology segment accounted for the largest market share in 2022 (32.4 %) and is expected to grow potentially during the forecast period. This dominance is explained by the growing prevalence of cancer worldwide, the continuous search for a wide range of drugs for their treatment. According to preliminary forecasts, the segment of infectious diseases will grow at a rapid pace with a projected cumulative average growth rate of 12.3 % until 2030. This growth is due to the urgency of developing effective, fast and cost-effective methods of treating infectious diseases.

According to the segment analysis of the global nanomedicine market by geographic regions in 2022, the dominant region in the market was North America (26.4 % of all capital investments of the total market volume). At the same time, the United States of America (57.9 %) and Canada (42.1 %) account for almost 100 % of capital investments in the North America region. Leading positions also belonged to the Asia-Pacific region (22.0 %) and Europe (19.8 %). The countries of Latin America and the Middle East and Africa accounted for 15.0 % and 16.8 %, respectively. According to preliminary forecasts, the fastest average cumulative growth rate of 14.1 % for the period from 2023 to 2030 is predicted for the market in the Asia-Pacific region, with a projected share of 21.4 %. These rates can be explained by increasing the awareness of the population of the region regarding the possibilities of nanomedicine and the active involvement of the public in various activities related to nanosciences and nanotechnologies.

The main factors affecting the dynamics of the global nanomedicine market and certain limitations regarding the possibility of using nanomaterials and nanotechnologies in medicine have been determined.

It has been found that the key trends in the development of the global nanomedicine market are personalized medicine and the combination of various treatment methods. The most promising innovative directions for the development of nanomedicine are singled out, and the prospects and conditions for the implementation of further scientific research in the field of nanomedicine have been defined.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship, or any other, that could affect the study and its results presented in this article.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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