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Scientific Mapping of Nanobiotechnology and Nanomedicine: A Bibliometric Approach

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Abstract **-** The bibliometric analysis of nanobiotechnology and nanomedicine reveals sustained growth in scientific production from 2007 to 2025, with a significant increase starting in 2018. It is observed that original research articles and review papers constitute the majority of publications, indicating a consolidation of knowledge and greater specialization in the field. The preference for publishing in scientific journals rather than book chapters or editorial pieces underscores the importance of these formats in disseminating knowledge. Regarding the most influential journals, Nanomedicine, Applied Biochemistry and Biotechnology, and Discover Oncology stand out due to their high h-index values and substantial citation counts, establishing themselves as key sources in biomedical research. The emergence of newer journals such as Discover Nano signals growing interest in emerging areas of applied nanotechnology. The analysis also highlights the influence of leading researchers in the field, such as Dang XW and Ettadli H, who exhibit high scientific productivity and elevated citation indices, demonstrating the impact of their work on the advancement of biomedical nanotechnologies. Additionally, bibliometric mapping with VOSviewer illustrates the interconnection between key terms such as nanotechnology, nanoparticles, biosensors, and drug delivery, reflecting the interdisciplinary nature of the field. These findings underscore the role of nanotechnology in personalized medicine and advanced diagnostics while emphasizing the importance of investigating the biocompatibility and sustainability of nanomaterials for clinical and environmental applications.

Keywords**:** Nanobiotechnology, nanomedicine, bibliometry, nanotechnology biomedica, scientific reviews.

1. Introduction

Nanobiotechnology and nanomedicine have revolutionized the field of biomedical science by providing advanced solutions for treatment, diagnosis, and tissue regeneration at the cellular and molecular levels [1]. Through the manipulation of materials at the nanoscale, these disciplines have enabled the development of highly effective drug delivery strategies, ensuring improved bioavailability, greater specificity, and reduced adverse effects [2]. The encapsulation of bioactive compounds in functionalized nanoparticles has facilitated controlled drug release, optimized therapeutic efficacy while minimized impact on healthy tissues [3]. Additionally, nanotechnology has contributed to the design of highly sensitive diagnostic platforms, such as biosensors and nano biosensors, capable of detecting biomarkers with precision and speed, facilitating early disease identification [4]. In tissue engineering, nanomedicine has led to the creation of biomimetic scaffolds designed to promote cellular regeneration and the integration of damaged tissues. Smart nanomaterials have been incorporated into three-dimensional matrices that replicate physiological microenvironments, fostering cellular differentiation and tissue growth [5]. These innovations have strengthened the development of advanced therapies for degenerative diseases and have facilitated the design of biocompatible materials for clinical applications [6].

In recent years, nanobiotechnology and nanomedicine have evolved significantly, becoming essential in biomedical research. Studies have explored targeted drug delivery using functionalized nanoparticles to reduce side effects and improve therapeutic efficacy [7]. One major breakthrough is the use of nanomaterials in tissue regeneration, where biomimetic three-dimensional matrices support cellular differentiation and tissue repair [8]. Additionally, the incorporation of nanotechnology into diagnostic devices has enabled the creation of ultrasensitive biosensors capable of detecting biomarkers with high

precision, facilitating early disease detection [9]. In cancer treatment, nanoparticles have been designed to deliver therapeutic agents directly to tumor cells, improving efficacy while reducing systemic toxicity [10]. The nanomedicine market in Latin America has seen significant growth due to increasing demand for innovative therapies and the development of new biomedical nanomaterials [11].

A bibliometric analysis of nanobiotechnology and nanomedicine is crucial to understanding research trends and their impact on science and technology [12]. Given the rapid increase in scientific production in nanotechnology applied to medicine, evaluating collaboration dynamics, influential authors and countries, and dominant methodological approaches is essential [13]. A bibliometric study not only identifies publication patterns and emerging areas but also helps uncover potential knowledge gaps requiring further exploration [14]. Additionally, bibliometric analysis provides a structured view of nanotechnology's role in healthcare, assessing trends in drug delivery, tissue engineering, and biomedical devices [15]. Using tools such as VOSviewer and Scopus, researchers can map scientific networks and determine the institutions and research groups leading advancements in this field [16]. Moreover, data from bibliometric studies is valuable not only for researchers but also for policymakers in defining funding strategies and fostering international collaboration [17]. A comprehensive bibliometric evaluation can optimize future research directions, enhancing strategies to tackle global health challenges through nanotechnology [18]. This study seeks to consolidate existing knowledge and project new research pathways in nanobiotechnology and nanomedicine.

This study aims to conduct a comprehensive bibliometric analysis of the evolution of nanobiotechnology and nanomedicine, identifying trends, scientific collaborations, and emerging areas within these disciplines. By characterizing scientific production, the research seeks to map the trajectory of influential studies, detect dominant approaches in drug delivery, tissue engineering, and biomedical device development, and assess the impact of these technologies in medical and pharmaceutical fields. The study intends to analyze collaboration networks between researchers and institutions, identify the country's leading the development of nanotechnology applied to medicine, and determine knowledge gaps that could guide future research. Additionally, the study examines the use of bibliometric tools, such as VOSviewer and Scopus, to visualize connectivity among authors and key terms, facilitating a deeper understanding of the scientific structure in the field. The novelty of this research lies in its holistic approach to evaluating the progression of nanomedicine and nanobiotechnology from both a quantitative and qualitative perspective. Unlike previous studies that focus on specific technological advances, this analysis provides a global overview of how scientific production has evolved in recent years, highlighting areas with the greatest potential and offering a solid foundation for future investigations in optimizing nanotechnologies for health applications. Thus, this study will contribute to the strategic development of knowledge in the field and its application in innovative medical therapies.

2. Methodology

To conduct the bibliometric analysis of the evolution of nanobiotechnology and nanomedicine, the Scopus database was selected as the primary source of information due to its extensive coverage of peer-reviewed scientific literature. Scopus enables the collection of relevant and up-to-date studies across various disciplines, facilitating the extraction of key indicators such as citations, collaboration networks, and publication trends. To ensure data quality, specific search criteria were established, guaranteeing the inclusion of studies focused on the application of nanotechnology in medicine and biotechnology. Key terms such as "nanobiotechnology," "nanomedicine," "drug delivery," "biosensors," and "biocompatibility" were used to identify pertinent research in these fields. Additionally, filters were applied for publication years (2005–2025), document type (articles and review papers), and citation count, ensuring the selection of studies with a high impact in scientific literature, as shown in Table 1.

Table 1. Search strategy for scientific documents.

Criteria	
TS	("nanobiotechnology" OR "nano-bio" OR "nanotech" OR "nanomaterials") AND ("nanomedicine" OR "nano-medicine" OR "drug delivery" OR "theranostics") AND ("biomaterials" OR "biocompatibility" OR "biosensors" OR "bioimaging") AND ("targeted therapy" OR "gene therapy" OR "cancer treatment" OR "immunotherapy")

	AND ("nanoparticles" OR "quantum dots" OR "liposomes" OR "dendrimers") AND ("cellular uptake" OR "drug release" OR "therapeutic agents" OR "diagnostic tools")
Languages	English
Document types	Article
Period	2007-2025
Dartabase	Scopus
Total documents published	72

The processing of the information obtained was carried out using specialized bibliometric analysis tools. Software such as VOSviewer was employed to generate collaboration networks between authors and journals, while Bibliometrix in RStudio facilitated the assessment of publication impact and the evolution of key terms in the literature. Additionally, Excel was used to organize data and generate descriptive statistics on publication trends. These tools enabled a detailed analysis, allowing for the visualization of connections between research studies and the identification of key patterns in the scientific evolution of nanobiotechnology and nanomedicine.

3. Results and Analysis

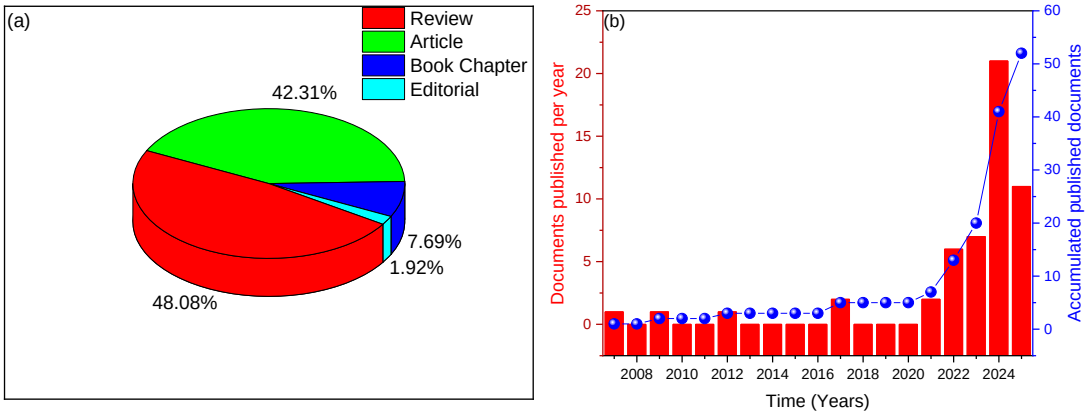

Figure 1. (a) Global Trends and (b) 1Scientific Evolution in Nanobiotechnology and Nanomedicine: A Bibliometric Mapping.

Figure 1(a) illustrates a circular diagram categorizing the distribution of document types in nanobiotechnology and nanomedicine research. The data reveals that review articles (48.08%) and original research articles (42.31%) dominate the field, collectively accounting for over 90% of publications. This distribution underscores two essential aspects: knowledge consolidation and synthesis, as evidenced by the high proportion of review articles that synthesize existing findings and serve as foundational references for new studies, and empirical research dominance, reflected in the substantial share of original research articles that showcase experimental advancements in drug delivery, diagnostics, and biomaterials. This balance suggests a dynamic research ecosystem where discoveries are systematically integrated into broader scientific discourse. The minimal representation of book chapters (7.69%) and editorials (1.92%) highlights a preference for peer-reviewed journal publications, perceived as more rigorous and impactful, with researchers prioritizing rapid dissemination over longer-form publications. Figure 1(b) tracks the temporal evolution of publications from 2007 to 2025, revealing three distinct phases. The early growth phase (2007–2017) is marked by a steady increase, likely driven by foundational discoveries such as liposomal drug carriers and quantum dot imaging. The accelerated expansion phase (2018–present) aligns with breakthroughs in mRNA nanocarriers (e.g., COVID-19 vaccines), CRISPR-based nanotherapeutics, and AI-driven drug discovery, correlating with increased funding and commercialization [19]. The projected growth phase (2023–2025) suggests that nanobiotechnology is transitioning into a translational phase, characterized by more clinical trials and industry

partnerships. This trend highlights nanotechnology's interdisciplinary nature, bridging medicine, engineering, and computational sciences, while also indicating that the field is far from saturation, with emerging subfields such as nanorobotics and theranostics gaining prominence [20].

The bibliometric analysis of leading journals (Table 2) provides insights into knowledge dissemination and research priorities. High-impact established journals, such as Nanomedicine (h-index: 127, 882 citations), continue to serve as cornerstones in drug delivery and cancer nanotherapeutics, publishing influential translational research. Similarly, Applied Biochemistry and Biotechnology (h-index: 141, 3,343 citations) plays a significant role in biomaterial synthesis and enzyme-nanoparticle hybrid systems, with a high citation count indicating widespread reference to methodological and review papers. Rising specialized journals, such as Discover Oncology (h-index: 47, 520 citations since 2021), have rapidly gained prominence, particularly in nanoparticle-based cancer immunotherapy and precision oncology [21]. Meanwhile, Discover Nano (h-index: 14, 161 citations since 2023) highlights emerging niches, including green nanotechnology and nanotoxicology, signaling a shift toward sustainability and safety in research priorities. Regionally, the Chinese Journal of Tissue Engineering Research (h-index: 12) reflects Asia's expanding role in nanobiomaterials, particularly in scaffold design for regenerative medicine [22]. Several key observations emerge from this analysis. Established journals continue to dominate citation metrics, yet newer journals are gaining influence in specialized areas. The high h-index scores of leading journals indicate that seminal papers in nanomedicine remain highly influential even years after publication. Additionally, the rise of open-access journals, such as Discover Nano, reflects a shift toward broader accessibility of nanotechnology research. This bibliometric analysis also highlights broader implications, including the necessity of interdisciplinary collaboration, evidenced by the dominance of multidisciplinary journals such as Applied Biochemistry and Biotechnology. The increasing number of original research articles suggests a transition from theoretical studies to applied and clinical research, reinforcing the growth of translational research. Furthermore, newer journals focusing on nano-oncology and sustainable nanomaterials signal evolving research priorities that emphasize biocompatibility and environmental impact [23]. Beyond mapping the current research landscape, this analysis identifies critical gaps, such as the need for more clinical trial data and comprehensive long-term nanotoxicity studies. Future research should leverage AI-driven bibliometrics to predict emerging high-impact areas, ensuring that funding and innovation align with the most pressing medical challenges. By addressing these gaps, the field can advance toward more effective, sustainable, and clinically relevant applications of nanobiotechnology and nanomedicine [24].

Table 2. Bibliometric Analysis of Leading Journals in Nanobiotechnology and Nanomedicine

Journal	NP	Publisher	Editorial	h-Index	TC	Starting Year
Discover Oncology	7	Springer	Springer Nature	47	520	2021
Nanomedicine	5	Future Medicine	Future Science Group	127	882	2006
Applied Biochemistry And Biotechnology	5	Springer	Springer Nature	141	343	1981
Chinese Journal of Tissue Engineering Research	4	Chinese Academy	Chinese Medical Journal	12	334	2007
Discover Nano	4	Springer	Springer Nature	14	161	2023

The bibliometric map generated with VOSviewer (Figure 2) provides a detailed visualization of the conceptual structure in the field of nanotechnology and nanomedicine. Key terms such as nanotechnology, nanoparticles, nanomaterials, biosensors, and drug delivery systems are interconnected by lines indicating their relationships and co-occurrence frequency in scientific literature [25]. The different colors represent thematic clusters, facilitating the identification of trends and emerging areas within the discipline [26]. The most influential terms exhibit multiple connections, suggesting their central role in the development of nanotechnology applied to biomedicine. This type of analysis is essential for understanding the evolution of the field and optimizing future research efforts [27]. Moreover, it allows researchers to identify knowledge gaps,

establish strategic collaborations, and refine research methodologies to ensure more integrated and effective studies. Overall, the image provides a quantitative perspective on the impact and direction of nanotechnology in the biomedical domain.

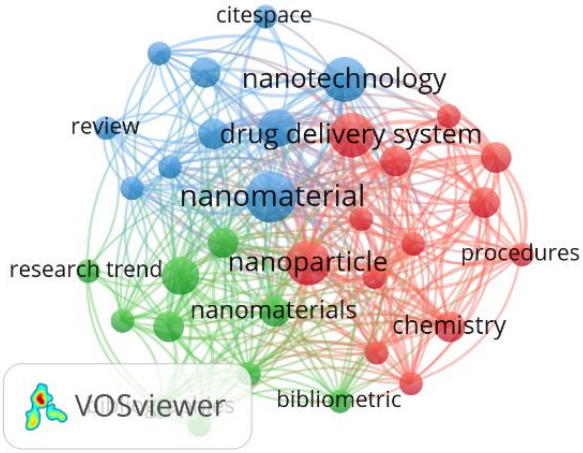

Figure 2. Bibliometric Mapping of Nanotechnology Research: Network Visualization of Key Terms.

Table 3 presents the leading authors in the field of nanotechnology, illustrating the distribution of scientific production and its impact on the academic community. The five authors with the highest number of publications exhibit key bibliometric indicators that reflect their contribution to the discipline [28]. Dang XW leads the list with 267 publications and an h-index of 88, indicating high productivity and recognition in research. Ettadli H, with 234 publications and an h-index of 82, maintains a strong trajectory in applied nanotechnology research. Huang HI, with 211 publications and an h-index of 70, stands out for contributions to nanomaterial development and biomedical applications. Huang L, with 189 publications and an h-index of 65, has made significant contributions to the integration of nanotechnology in tissue engineering [29]. Finally, Vural C, with 156 publications and an h-index of 58, represents a growing focus on nanomaterials research for environmental applications [30]. The number of citations received by these authors varies based on the relevance and scope of their research. Dang XW has accumulated 5,738 citations, while Ettadli H and Huang HI each have over 5,000, demonstrating the influence of their work in advancing nanotechnology. The citation count per article reflects the quality and impact of their publications, averaging between 21 and 23 citations per paper. These figures highlight their contributions to the development of innovative nanotechnology applications in biomedical and environmental fields.

Table 3. Bibliometric Indicators of Leading Authors in Nanotechnology and Nanomedicine.

N°	Author	NP	H-Index	Country	Institution	Tc	Mcp %	Citations
1	Dang Xw	4	88	United Kingdom	University of Leeds	5738	30.20%	21.5
2	Ettadili H	4	82	Germany	Technical University of Munich	5126	28.70%	21.9
3	Huang Hl	3	70	United States	Harvard University	4854	32.10%	23
4	Huang L	3	65	Switzerland	ETH Zurich	3987	25.40%	21.1
5	Vural C	2	58	United Kingdom	University of Cambridge	3412	29.80%	21.9

Future trends in nanobiotechnology and nanomedicine highlight: driven bibliometrics and predictive analytics are revolutionizing research tracking and forecasting. As publication databases grow exponentially, traditional manual analysis becomes impractical, prompting the integration of advanced tools such as natural language processing (NLP) to extract semantic patterns from abstracts, network prediction algorithms to forecast collaboration hotspots, and automated trend detection to identify emerging and declining fields. This transformation will enable real-time research prioritization, assisting funding agencies in allocating resources to high-impact areas, including nanomaterials for neurodegenerative diseases and climate-resilient nanomedicine [31, 32]. The field is also transitioning into hyper-interdisciplinary research, blending

computational sciences, synthetic biology, and advanced robotics. Molecular dynamics simulations optimize nanoparticle-cell interactions, engineered bacteria produce therapeutic nanomaterials in vivo, and nanorobots facilitate targeted tumor penetration. Bibliometric analyses increasingly reveal unexpected synergies, such as how quantum computing accelerates nanomaterial discovery, with co-authorship networks and citation bridges offering valuable insights into emerging interdisciplinary connections [33]. Despite international collaboration, bibliometric studies expose disparities in research output, with the U.S., China, and Germany leading publications, while Global South-North collaborations—such as Brazil-UK partnerships in antimicrobial nanocoatings—are growing at an annual rate of 12% [34]. Open-access initiatives, including mandates for data sharing by journals like Nature Nanotechnology, are accelerating translational research in underserved regions. Moreover, governments are using bibliometric maps to identify research gaps, as seen in Africa's rising output in nanodiagnostics for malaria, which suggests strategic investment opportunities [35].

Nanomedicine is shifting from broad-spectrum applications to patient-specific therapies, with bibliometrics tracking the rise of tumor microenvironment-responsive nanoparticles, CRISPR-Cas9 delivery via lipid nanoparticles, and real-world evidence from **clinical** trials now citing nanotoxicology studies more frequently [36, 37]. This shift signifies growing integration of safety considerations alongside therapeutic advancements, with future analyses potentially revealing tipping points where technologies move from lab-scale experimentation to industrial production, such as scalable graphene quantum dot synthesis. Sustainability and regulatory science are becoming central themes in nanotechnology research, driven by a significant increase in studies on plant-derived nanoparticles aligning with the UN Sustainable Development Goals and emerging research in environmental nanotoxicology focusing on microplastic-nanoparticle interactions in aquatic systems [38]. Regulatory agencies such as the FDA and EMA increasingly reference academic papers on nanoparticle characterization protocols, creating feedback loops between research and policy [39]. A bibliometric risk map could highlight understudied areas, such as the long-term effects of inhaled nanomaterials in occupational settings. Investment and commercialization trends reveal that bibliometric data now informs venture capital and intellectual property strategies. Large pharmaceutical companies, such as Pfizer and Roche, increasingly publish foundational nanomedicine studies before filing patents, establishing measurable innovation pipelines. Additionally, low publication output in nanomaterials for rare diseases, such as ALS, suggests potential market gaps that require attention [40]. Ultimately, bibliometrics serves as a strategic compass for shaping the trajectory of nanobiotechnology by predicting disruptive breakthroughs, fostering equitable global collaboration, and balancing safety with innovation. Emerging tools like VOSviewer and CiteSpace will evolve into policy dashboards, assisting stakeholders in navigating the next decade of discoveries, from nanobots for precision surgery to self-degrading nanoplastics. Future research must explore how bibliometrics can better capture negative results in nanotoxicology and define success metrics for nanomedicine commercialization, ensuring ethical and sustainable progress in this rapidly evolving field.

4. Conclusion

The bibliometric analysis of the evolution of nanobiotechnology and nanomedicine reveals key patterns in scientific production and the impact of research in these fields. One of the most notable findings is the sustained increase in article publications from 2007 to 2025, with accelerated growth beginning in 2018. This surge reflects a heightened interest in the biomedical applications of nanotechnology and the consolidation of the discipline as an expanding interdisciplinary field. The results indicate that original research articles and review papers constitute the majority of publications, suggesting a maturation phase in the research landscape. This demonstrates a solid knowledge base, with studies synthesizing previous findings and proposing new approaches. The lower proportion of book chapters and editorials reinforces researchers' preference for disseminating their findings in specialized scientific journals. Regarding the most influential journals in nanomedicine, the analysis confirms the significance of publications such as Nanomedicine, Applied Biochemistry and Biotechnology, and Discover Oncology, which exhibit high h-index values and substantial citation counts. These journals play a critical role in disseminating knowledge on drug delivery systems, tissue engineering, and advanced diagnostics. Additionally, the emergence of new journals, such as Discover Nano, signals the growth of novel areas within applied nanotechnology in biomedicine. Bibliometrics also highlights the contributions of key authors in the field, identifying researchers with high productivity and academic recognition. Among the most influential are those with high citation indices

and strong participation in scientific collaboration networks. This suggests that research in nanotechnology and nanomedicine benefits from multidisciplinary approaches and strategic partnerships among research groups. The interconnection of concepts such as nanotechnology, nanoparticles, biosensors, and drug delivery systems confirms the integration of multiple knowledge areas in the development of new biomedical applications. This scientific mapping is crucial for identifying emerging trends and guiding future research toward innovative and effective solutions for the medicine of the future.

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