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MORALITY BEFORE KNOWLEDGE

The role of policies in supporting biodegradable medical innovations for sustainable healthcare systems: A research review

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ABSTRACT

Background: The global health crisis is a complex issue that requires coordinated efforts among individuals, organizations, and institutions. In this context, health policies play a crucial role in improving quality of life and population well-being. With the growing development of medical innovations based on biodegradable materials particularly in the advancement of medical devices and technologies strong policy support is essential. Such policies are expected to promote the adoption of sustainable innovations through the use of biodegradable materials, which not only have the potential to enhance healthcare effectiveness but also to support the long-term sustainability of health systems in the future. **Methods:** This study employs a literature review method to examine the role of policy in supporting medical innovation based on biodegradable materials for healthcare system sustainability. Secondary data were obtained from peer-reviewed journal articles published between 2020 and 2025 and indexed in Google Scholar. **Findings:** This study demonstrates that public policy plays a strategic role in accelerating medical innovation based on biodegradable materials to achieve a sustainable healthcare system. Through research support, regulation, and funding in various countries such as the European Union, the United States, China, and Japan, the development of eco-friendly biomaterials such as PLA, PCL, and magnesium composites has been promoted to reduce environmental impacts while enhancing the efficiency and resilience of the healthcare sector. **Conclusion:** The synergy between public policy and biomedical innovation using biodegradable materials is essential for creating a sustainable and resilient healthcare system. Government support and sustainability-oriented policies foster energy efficiency, renewable energy adoption, and effective waste management worldwide. **Novelty/Originality of this article:** This study emphasizes that integrating public policy with biodegradable-based medical innovation is vital for building a sustainable healthcare system. By combining policy, biomedical engineering, and environmental perspectives, it offers a more comprehensive approach than previous studies. The findings show that strong policy–innovation synergy can lay the groundwork for future sustainable healthcare development.

KEYWORDS: biodegradable; literature review; medical innovations; policies; sustainability.

1. Introduction

The term health policy can be considered somewhat ambiguous. It has been clearly defined as a policy intended to improve population health and is often regarded as synonymous with healthy public policy (de Leeuw et al., 2014). National Public Health Institutes (NPHIs) and WHO Collaborating Centres (WCCs) serve as vital components of global networks that enhance public health systems, advance Essential Public Health

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Functions (EPHFs), and provide the evidence base needed to inform health policy (Jakab et al., 2021). Health policies need to consider societal perceptions and interpretations of a disease's origins and causes, while media outlets play a crucial role in shaping the public narrative around health issues (Dalglish et al., 2020). Policymakers and multilateral institutions are increasingly recognizing that sustainable growth cannot be separated from environmental issues, as ecological degradation will ultimately weaken the economy (Moshood et al., 2021). Managing a global health crisis is inherently complex, demanding coordinated efforts across individuals, organizations, and institutions, and relying on extensive collaboration through both interdisciplinary and multidisciplinary approaches (Liu et al., 2020).

Over the past few decades, the amount of medical waste has increased significantly, driven by the continuous advancement of medical technology and the growing intensity of healthcare services and medical procedures. The emission of harmful gases can result from the open-air storage of medical waste, such as methane and sulfide, which have the potential to cause severe air pollution. In addition, the incineration of medical waste also releases polychlorinated biphenyls (PCBs) and dioxins, which are carcinogenic compounds that pose risks to both human health and the environment (Wei et al., 2020). This issue has led to an increasing demand for biodegradable materials, which are substances that can decompose through biological processes. These materials are often combined with environmentally friendly products and can break down into natural elements. With proper control, they can play an important role in reducing environmental pollution. Materials such as PBS, PBAT, PCL, PVA, and PLA are considered to have great potential as alternatives to conventional plastics due to their ability to reduce environmental pollution (Kangming Tian, 2020). The production of biodegradable plastics shows a higher amount compared to non-biodegradable plastics each year, indicating a consistent increase (Fig. 1).

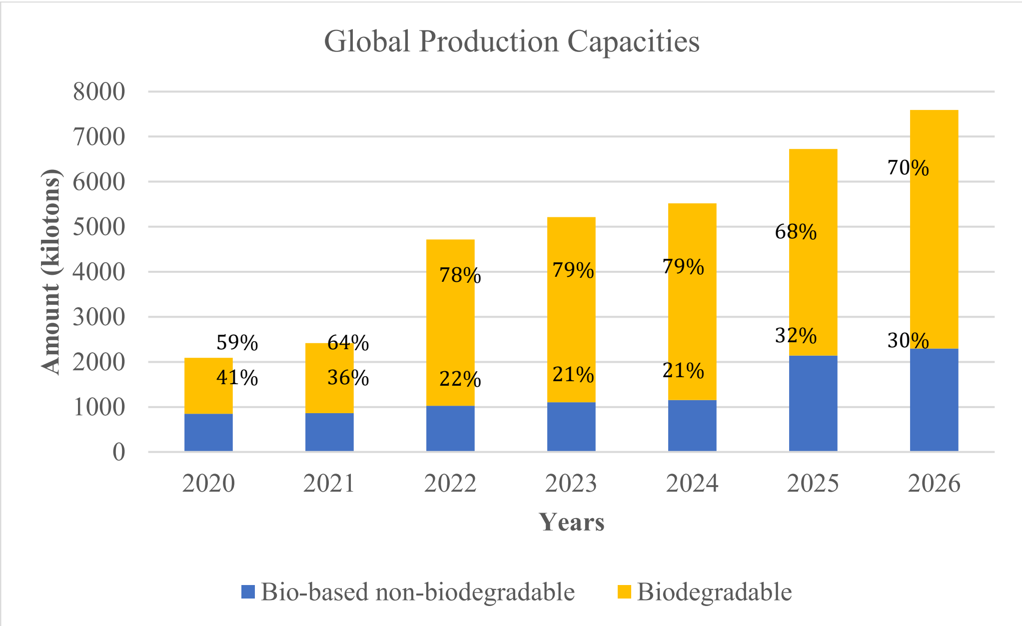

Fig. 1. Percentage of global production capacities over the years (Kim et al., n.d.)

Biodegradable materials are closely related to both natural and synthetic polymers. Since synthetic polymers can be toxic and induce immune responses, natural and biodegradable polymers serve as a superior alternative for the development of nanoparticles in various biomedical applications (Kučuk et al., 2023). Both natural, synthetic, and metal-based biodegradable materials such as magnesium, zinc, and iron are now widely used in the medical field (Shu, 2025). Biodegradability is one of the main advantages of natural polymer materials, making them environmentally friendly and highly promising for various medical and industrial applications. Furthermore, the advantages and disadvantages of different types of polymers, both synthetic and natural, can be analyzed to understand their characteristics, performance, and potential for future development, as illustrated schematically in Figure 2, which presents a comparison and examples of both types of polymers (Fig. 2).

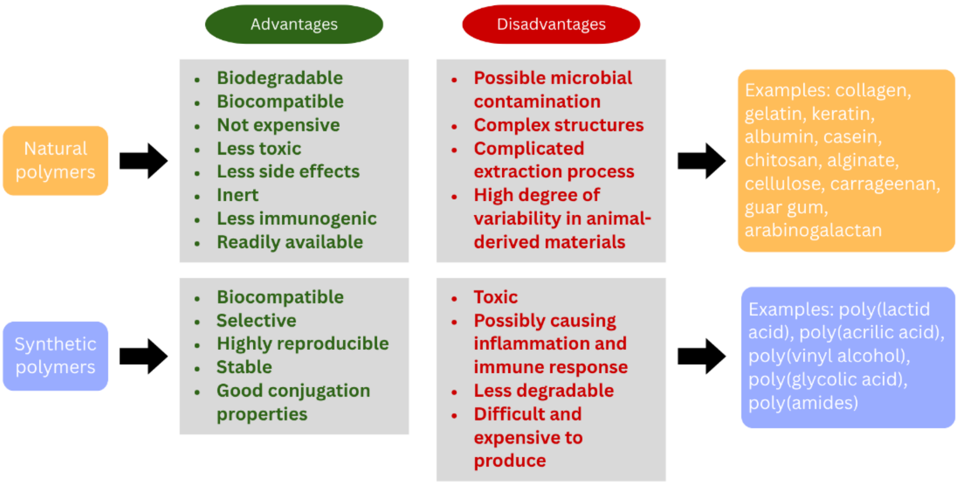

Fig. 2. Advantages and disadvantages of natural and synthetic polymers (Kučuk et al., 2023)

The applications of biodegradable materials cover various areas of tissue engineering, including orthopedic scaffolds, cardiovascular systems, dental treatments, and wound healing. In addition, biodegradable materials play an important role in drug delivery and disease therapy, such as cancer treatment, degenerative diseases, and skin wound healing, all of which contribute to the advancement of more environmentally friendly and sustainable medical technologies (Shu, 2025). Several medical innovations, such as Next-Generation Sequencing (NGS), 3D-printed devices, immunotherapy, Artificial Intelligence (AI), Point-of-Care (POC) diagnostics, Virtual Reality (VR), biosensors, and telehealth (Deloitte, 2016). One of the applications of biodegradable polymers is in the treatment of various bone disorders. Recent developments in material technology have expanded the range of materials that can be utilized for orthopedic implant fabrication (Liang et al., 2023). In addition, the application of manufacturing technologies, such as electrospinning, can significantly expand the opportunities for developing sustainable biomaterials (Panahi, 2025). Government innovation policy programs aim to encourage and facilitate innovative activities in addressing various environmental issues. One of their main roles is to support research and development (R&D) by providing incentives and funding for companies engaged in both basic and applied research (Naruetharadhol et al., 2024).

This article is structured to provide a comprehensive overview of global policies related to various sectors and their connection to medical innovations based on biodegradable materials. The discussion includes the classification and application of biodegradable materials in the medical field, as well as the concept of sustainability in healthcare systems, analyzed through literature sources from the Google Scholar platform. The purpose of this study is to analyze the role of global policies in promoting medical innovation based on biodegradable materials to support the sustainability of health systems that provide various positive impacts. The study by Naruetharadhol et al. (2024) serves as an important reference, offering a global perspective on the impact of government policies in promoting eco-innovation while complementing studies focused on specific regions. The research emphasizes that government support plays a crucial role in achieving a sustainable green future with economic value. Therefore, within the context of this article, public policy aspects are considered highly relevant in supporting medical biodegradable innovation to ensure an efficient and environmentally conscious healthcare system.

2. Methods

In analyzing the complex nature of eco-innovation policies across various countries, Naruetharadhol et al. (2024) employs a qualitative methodological approach. The countries included in this study are members of the European Union, Japan, China, the United States (US), Brazil, the United Kingdom, and Thailand. A qualitative method enables an in-depth understanding of policy contexts, stakeholder perspectives, and the complex interactions among various factors shaping innovative initiatives. Thematic analysis is utilized to comprehend the complexity of policies at both national and global levels. Research on cross-sectoral policy development with integrated environmental issues in global health governance was conducted by Evrard et al. (2025), emphasizing the close relationship between environmental issues and global health. Data were collected from the Institutional Repository for Information Sharing (IRIS) database and the WHO website. Data analysis was performed using Python with relevant packages such as Pandas, Numpy, and MatPlotLib. The results indicate several thematic entry points that can be utilized to further integrate environmental issues into global health governance.

This section elaborates on the research methodology employed to analyze data in addressing the primary research question regarding the role of public policy in promoting medical innovation based on biodegradable materials to support healthcare system sustainability. This study utilizes a comprehensive literature review approach by drawing upon secondary data sourced from reputable scientific journal articles indexed on the Google Scholar platform. The reviewed literature incorporates interdisciplinary perspectives to ensure the inclusion of studies related to public policy, biomedical engineering, environmental sustainability, and global healthcare systems. The data collection process involved selecting articles published between 2020 and 2025 to capture the most recent developments and policy directions concerning sustainable medical technologies. The article selection procedure was carried out through a multi-stage screening process, which included identifying relevant keywords, initial screening based on the alignment of titles and abstracts with the research topic, and a thorough assessment of eligibility and relevance. Only articles that specifically address policies, related case studies, regulatory frameworks, or government initiatives supporting medical innovations particularly those involving biodegradable materials were included in the final dataset.

Following the selection process, the articles were systematically evaluated using thematic content analysis to identify recurring patterns, policy strategies, and technological implications contributing to sustainable healthcare practices. This method enables the synthesis of diverse findings into a structured understanding of how public policy interventions facilitate the research, commercialization, and adoption of biodegradable-based medical technologies. Ultimately, this research design aims to generate comprehensive insights that strengthen the academic foundation for future studies and provide strategic recommendations for policymakers in enhancing sustainable innovation within global healthcare systems.

This study involves a systematic analysis of existing scholarly articles to explore and deepen the understanding of the interconnected relationship between public policy, medical innovation, biodegradable materials, and the sustainability of healthcare systems. The literature selected for review encompasses various global perspectives and policy frameworks to ensure a broad and inclusive representation of current developments. Each publication was evaluated using a thematic analysis approach, focusing specifically on how governmental policies in different countries influence and support research and development, regulatory approval processes, and the practical implementation of environmentally friendly medical technologies. Through this detailed evaluation, the study aims to identify best practices, challenges, and policy gaps that may affect the adoption of sustainable innovations in healthcare. By applying this rigorous method, the research is expected to provide a more comprehensive, structured, and measurable overview of the role that public policy plays in accelerating the advancement of biodegradable-based medical innovation. Additionally, the outcomes are expected to provide valuable insights that serve not only as a foundation for further academic study but also as guidance for future policymaking to strengthen sustainable healthcare development worldwide.

3. Results and Discussion

3.1 Overview of biodegradable medical innovations

Biodegradable medical innovations, particularly medical implants, represent sustainable and biocompatible solutions for the future of medical practice. The types of biodegradable implants have rapidly evolved and encompass various medical applications, such as biodegradable cardiovascular implants, biodegradable implants for in vivo drug delivery, biodegradable nerve repairing implants, biodegradable orthopedic implants, biodegradable implants for wound healing, biodegradable urological implants, and biodegradable sensors. Biodegradable-based innovations offer diverse solutions for the development of implantable devices, tissue repair, and the implementation of sustainable medical technologies (Xia et al., 2025). In recent years, various types of copolymers have been investigated for bone regeneration applications, and the *polylactide/polyglycolide* copolymer has emerged as a highly promising material. The development of copolymers serves as a better alternative, as it can minimize the limitations of single polymers due to the favorable characteristics of biodegradable polymers for medical use (Oleksy et al., 2023). One of the sustainable manufacturing methods applied in the development of biodegradable biomaterials is 3D printing technology. This technology offers various advantages and holds great potential for continued advancement in the future. One notable example of its application is in the production of protective masks used during the coronavirus pandemic (Pesode et al., 2023).

At present, medical biodegradable metal materials are primarily used in fields such as neural implants, vascular stents, and orthopedic implants. Magnesium, zinc, iron, and molybdenum are biodegradable metals with superior characteristics for various medical applications and implantable electronic devices. Magnesium is widely used for bone repair due to its compatibility with human tissue, while zinc offers high strength and excellent biocompatibility. Iron, with its ferroelectric properties, holds great potential in the development of implantable electronic devices owing to its piezoelectric capability, whereas molybdenum is extensively utilized as an electrode material in implantable devices and energy storage systems (Chu et al., 2025). In most cases of spinal diseases, conventional procedures such as spinal fusion or discectomy often cause injury to the surrounding tissues. As an alternative, a minimally invasive biodegradable implant in the form of a nucleus pulposus (NP) scaffold has been developed with functional regenerative capability to repair tissue damage more safely and effectively (Wang et al., 2023).

One of the medical innovations based on biodegradable materials developed to address various neurological disorders, including epilepsy, Alzheimer's disease, Parkinson's disease, depression, and chronic pain, is the biodegradable neural implant with sensors. This implant functions in mapping and monitoring brain activity at various stages, including pre- and intraoperative, postoperative, and recovery phases following injury or drug therapy (Alam et al., 2024). The transition from conventional plastics to biodegradable alternative materials such as those based on PHA, PLA, PGA, PCL, PLGA, starch-based, and PBS in medical equipment presents both challenges and new opportunities (Moshkbid et al., 2024). Poly(L-lactic acid) (PLLA), a biodegradable polyester approved by the Food Drug Administration (FDA), is widely utilized in biomedical applications, including drug delivery systems, tissue engineering, and various medical devices, due to its semi-crystalline properties (Dallaev et al., 2025). In 2023, PLA polymer was recorded as the most widely produced biodegradable material globally, with a production share reaching 31.0%, as shown in Fig. 3.

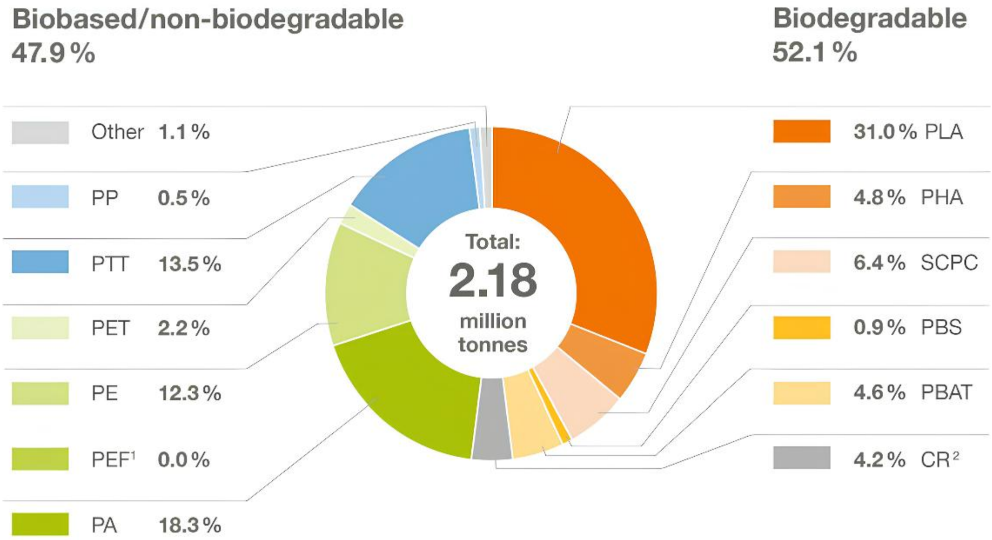

Fig. 3. Global production capacities of BP types in 2023
(Moshkbid et al., 2024)

Biodegradable plastics are developed for their ability to naturally decompose into water, carbon dioxide, and biomass through microbial activity. Their application plays an important role in reducing the environmental impact of plastic waste and promoting sustainable material management in line with recycling efforts (Alaghemandi, 2024). An ideal biomaterial should be non-toxic to the body, biocompatible to allow interaction with tissues without triggering immune reactions, and possess good mechanical properties to ensure structural strength and stability. Furthermore, the biomaterial should be flexible and deformable, promote cell proliferation for tissue regeneration, and be biodegradable (Kurowiak et al., 2023). Biodegradable polymers play a crucial role in the fabrication of resorbable medical devices as well as organ and tissue prototypes. One prominent example is polylactic acid (PLA), which is widely utilized in biomedical applications for the development of scaffolds, biodegradable fibrous medical textiles, orthopedic screws, biocomposite materials, and surgical sutures. Moreover, low-molecular-weight PLA is also employed in tissue engineering to support cell regeneration and tissue repair (Dallaev, 2025).

Single-use technologies (SUT) play a significant role in enhancing the efficiency of biomanufacturing processes. Unlike conventional stainless-steel systems that require thorough cleaning and sterilization between each production cycle, single-use components are pre-sterilized and ready to use, allowing faster setup, reduced downtime, and improved operational efficiency. This level of flexibility is particularly crucial in multiproduct facilities, where rapid changeovers are necessary to accommodate diverse production demands (Sanket J & Ankitkumar N, 2017). The utilization of biodegradable materials in medical products has been widely developed from various plant derivatives. These materials share similar characteristics with conventional synthetic fibers, such as low density, high stiffness, and good mechanical strength. The use of plant-based derivatives in medical applications offers several advantages over synthetic materials, depending on their type and function, due to their antimicrobial, biodegradable, and other beneficial properties. Common plant sources include maize, cotton, potato, cassava, flax, bamboo, pineapple, and banana, each possessing unique characteristics that determine their specific applications in the medical field (Najeeb, 2025).

Another example of biodegradable medical innovation is the microneedle (MN) delivery device. MNs made from biodegradable polymers offer advantages over those made of silicon, metal, glass, or non-biodegradable polymers, as they are easier to fabricate, suitable for mass production, cost-effective, and biologically degradable (Starlin Chellathurai et al., 2024). Beyond medical innovations, the application of biodegradable materials has also been expanding in food packaging through the concept of green chemistry, introducing novel approaches with significant potential to promote sustainability (Jahangiri et al., 2024). Biodegradable biomaterials are extensively utilized in orthopedic surgery, serving various purposes such as fixation, filling, and temporary structural support. The primary goal of biodegradable fixation materials is to prevent biomechanical complications that may sometimes occur with non-resorbable materials, which could otherwise require implant removal (Raitio et al., 2024).

3.2 Policy initiatives supporting biodegradable innovations

Policies play a crucial role in evaluating the feasibility and implementation of proposed actions or practices (Muriithi & Ngare, 2023). Extended Producer Responsibility (EPR) is a policy for managing the lifecycle of plastic products that places recycling responsibility on producers. This program has been implemented in various countries across Europe, Asia, and North America, showing positive results in reducing plastic waste and increasing recycling rates. In Germany, for example, producers are required to finance the collection, sorting, and recycling processes as part of the national waste management system (Alaghemandi, 2024). The medical device, biotechnology, and healthcare industries rely heavily on innovation through research, development, and the introduction of new products. Javanmardi et al. (2024) introduced the Dynamic Sustainable Business Model (DSBM) for the Health-Tech sector, which integrates adaptability and sustainability to help companies effectively leverage emerging technologies.

Although numerous studies have highlighted the role of policy in driving demand for sustainable products and services, understanding of the contribution of incumbent companies in expanding innovations that support the transition toward sustainability remains limited (Bor et al., 2024). The establishment of a strong regulatory framework is essential to ensure the safety and effectiveness of medical devices. In the European Union, the Medical Device Regulation (MDR) requires strict pre-market assessments and post-market surveillance to guarantee patient safety. The Food and Drug Administration (FDA) in the United States applies similar standards through extensive clinical trials and continuous monitoring after market entry. Meanwhile, in Japan, requirements for domestic clinical data and a complex reimbursement system often slow down the approval process, leading to a phenomenon known as “medical device lag” (Amaral et al., 2024).

When redesigning plastic products to be more environmentally friendly, it is important to consider the entire lifecycle of the material. A life cycle assessment (LCA) should be conducted from the early design stage and updated regularly, then compared with conventional plastics. Plastic sustainability goes beyond biodegradability or recyclability, encompassing water and energy consumption as well as greenhouse gas emissions throughout all stages from raw material extraction to production, use, and disposal or recycling (Quinn et al., 2023). The biotechnology (biotech) sector has experienced significant growth in recent years. In the European Union, the number of researchers in this field has nearly doubled, increasing from 42,000 in 2012 to around 81,000 in 2021. Meanwhile, in the United States, the number of employees in the biotechnology industry has also risen sharply, from approximately 135,000 in 2012 to nearly 300,000 in 2023. Overall, the biotechnology sector in the United States employs about three times more workers than in the European Union (Joint Research Centre, 2024).

Biotechnology oversight in Nigeria involves several agencies, including the National Biosafety Management Agency (NBMA), National Environment Standards and Regulations Enforcement Agency (NESREA), and National Agency for Food and Drug Administration and Control (NAFDAC). Its development is influenced by the country’s diverse ecological conditions and rich biodiversity in regions such as the Niger Delta and the savannas, which encourage the use of biotechnology for the conservation and sustainable management of natural resources. Environmental challenges, including deforestation, soil degradation, and water pollution, have further strengthened the role of biotechnology in sustainable agriculture and bioremediation (Ojeih et al., 2024). The researchers emphasized the need for further evidence on the effectiveness of various mechanisms in addressing industry influence. This study seeks to strengthen these efforts by examining policies and research related to industry funding, affiliation, and conflicts of interest (COI) in biomedical research to support the development of more effective future policies (Graham et al., 2025).

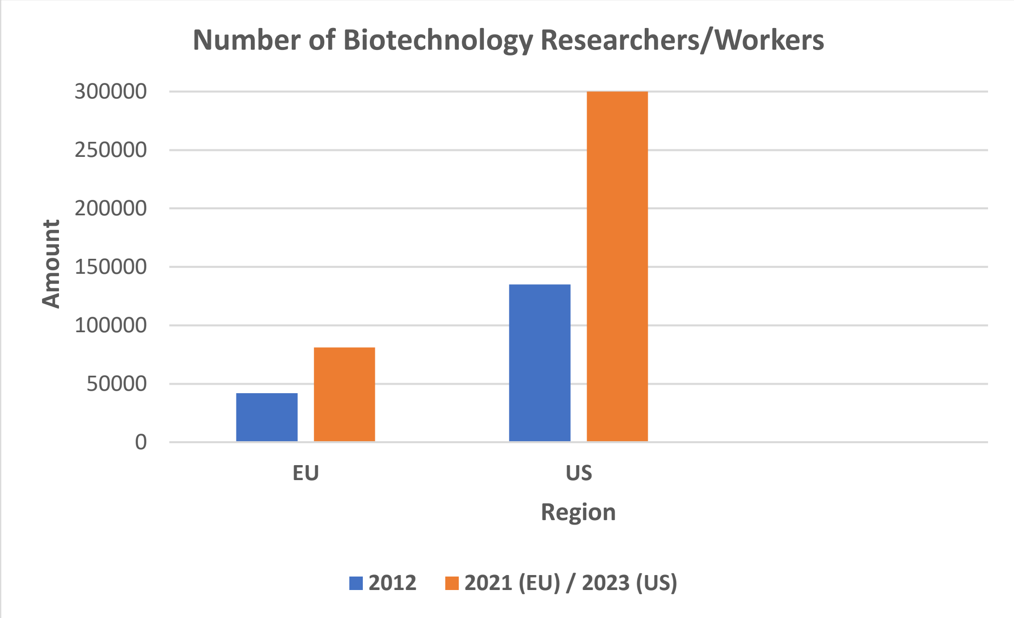

Fig 4. Number of biotechnology researchers/workers
(Joint Research Centre, 2024)

The growing global demand for environmentally friendly chemicals has driven the significant expansion of the bio-based polymer market. Research in functional polymer synthesis continues to advance, emphasizing biodegradability and natural decomposition as key solutions to waste management challenges. Moreover, progress in utilizing biomass as a raw material source has accelerated innovation in the development of bio-based materials and products (Joseph et al., 2023). Regulatory aspects and policy recommendations at the global level play a crucial and strategic role in guiding the development of a resilient and sustainable healthcare supply chain system. With the rapid evolution of medical technologies, increasing environmental concerns, and the growing complexity of global health challenges, an adaptive regulatory framework is essential to ensure that healthcare systems can respond effectively to disruptions while maintaining service quality and patient safety. Global policy initiatives not only help harmonize standards across countries but also encourage international collaboration, innovation adoption, and investment in environmentally responsible medical products, including those made from biodegradable materials (Apeh et al., 2024).

3.3 Comparative analysis of policy implementation

One successful example of sustainable policy implementation is the collaboration between Kaiser Permanente and Practice Greenhealth, which has effectively reduced environmental impacts through the use of renewable energy, improved waste management, and the adoption of sustainable procurement systems. Similarly, the National Health Service (NHS) in the United Kingdom has undertaken comparable initiatives by lowering carbon emissions through the use of electric ambulances and the implementation of environmentally friendly procurement strategies (Paul et al., 2024). Governments around the world play a crucial role in advancing nanotechnology research through funding mechanisms such as grants, specialized research programs, and national initiatives focused on innovation. The United States is one of the pioneers in this field, having established the National Nanotechnology Initiative (NNI) in 2000, which allocates more than USD 1.5 billion annually for nanotechnology research and development, involving over 20 federal agencies such as the Department of Energy and the National Institutes of Health. China is currently the largest global investor in nanotechnology, with annual investments exceeding USD 1.5 billion as part of its national five-year development plans. The country's primary focus includes the development of nanomaterials, nanomedicine, and energy applications. In Europe, the European Union supports the advancement of nanotechnology through the Horizon 2020 program, which allocated more than €2.7 billion for nanotechnology-related projects during the 2014–2020 period. This collaborative funding model has played a significant role in accelerating research and the application of nanotechnology across various industrial sectors (Khatoon & Velidandi, 2025).

The European Commission has established comprehensive biodegradability standards for relevant products, formulated through an extensive evaluation process based on the latest findings from scientific and technical studies that incorporate advanced biodegradation prediction models. These standards are designed to ensure that materials entering the market are capable of breaking down within environmentally acceptable timeframes, thereby minimizing ecological impact, supporting circular economy objectives, and promoting innovation in sustainable product development across various industrial sectors (Domínguez-Solera et al., 2025). Global Health Reciprocal Innovation (GHRI) is a modern research approach that emphasizes the recognition and development of innovations such as drugs, medical devices, and research methodologies originating from low- and middle-income countries (LMICs). Currently, GHRI efforts are primarily focused on adapting innovations from LMICs for application in high-income countries (HICs), as these resource-efficient solutions often offer cost-effective and scalable alternatives to existing technologies. In addition to this adaptation approach, a growing body of research emphasizes collaborative development models that engage stakeholders from both settings throughout the entire innovation process ranging from problem identification and prototype design to validation and implementation to ensure that resulting solutions are contextually appropriate, equitable, and mutually beneficial. This shift highlights an increasing recognition of the value of bidirectional learning and co-creation in advancing global health outcomes (Rid et al., 2024).

Policy support and increasing investments have strengthened India's biotechnology sector in addressing environmental challenges and promoting sustainable economic growth. Through innovation and the application of circular economy principles, the industry plays a key role in reducing dependence on fossil fuels by producing biofuels, bioplastics, and biofertilizers (Vandy et al., 2025). The development of biomaterial-based medical devices has become increasingly complex, driven by advancements in material discovery that demand regulatory adaptation. In the European Union, the approval process is governed by the updated Medical Device Regulation (MDR) and In Vitro Diagnostic Regulation (IVDR), which reflect these advancements. However, the lack of international regulatory harmonization and poor data reporting quality remain major challenges. To date, no adequate solutions have been established to effectively accelerate the translation of biomaterials into clinical practice (Jurczak et al., 2025).

Biomedical engineering encompasses a wide range of applications that significantly contribute to advancements in healthcare. It involves developing innovative solutions to medical challenges, designing and maintaining medical equipment, and improving patient treatment through technological progress. Biomedical engineers play a crucial role in the development of artificial organs, advanced diagnostic tools, and treatment facilities, as well as in healthcare management and clinical engineering. Their multidisciplinary expertise enables them to bridge the gap between engineering principles and medical sciences, leading to innovations that improve disease detection, enhance therapeutic effectiveness, and ensure patient safety. Additionally, biomedical engineers contribute to the optimization of hospital operations, the integration of digital health technologies, and the maintenance of high-performance medical equipment, all of which are essential to strengthening healthcare systems and supporting better health outcomes on a global scale. Their expertise supports the analysis of patient conditions, problem-solving in healthcare systems, and the creation of life-changing medical devices. Furthermore, the field contributes to the manufacturing of tissue architectures, the design of artificial joints, and continuous technological improvements. By integrating engineering principles with contemporary biological understanding, biomedical engineering drives medical research and transforms the future of healthcare (Javaid et al., 2023).

3.4 Sustainability impacts of policy-driven innovations

In the implementation of sustainable research and development, public policy should provide substantial support. This can be achieved by increasing funding for research institutions and universities, as well as offering incentives to the private sector to participate in research and development investments. Consistent support for research activities also has the potential to foster innovation and new discoveries that contribute to addressing environmental and social challenges (Mahardhani, 2023). The impacts that emerged include economic recovery and support, the implementation of public health measures, an emphasis on social protection and inclusion, and increased investment in research and development. Furthermore, there has been a growing emphasis on enhancing social protection systems and promoting inclusion, particularly for vulnerable groups who are disproportionately affected during times of crisis. In addition, governments and institutions have significantly increased investments in research and development, recognizing that scientific innovation is essential for advancing healthcare solutions, improving preparedness for future emergencies, and fostering sustainable long-term development (Goniewicz et al., 2023). The medical device industry remains highly dependent on carbon emissions and needs to strengthen its efforts in implementing environmentally conscious practices. Around 60% of healthcare professionals believe that further progress is still needed to achieve sustainability goals (Montesinos et al., 2024).

Government and federal funding play a highly significant role in driving the advancement of medical innovations utilizing biodegradable materials. This financial support not only accelerates research and development processes but also helps reduce various economic risks that may be encountered by researchers and startups in the field. As a result, they are able to focus more effectively on creating sustainable healthcare technologies that deliver meaningful benefits to society. Therefore, proactive health policies focused on sustainable innovation funding are key to driving the development and commercialization of medical devices that integrate smart biomaterials and nanomedical technologies (Hosseini et al., 2021). Future technologies have the potential to enhance the accuracy, effectiveness, accessibility, and cost efficiency of healthcare services. However, many innovative therapies remain accessible only to those with financial means. Therefore, reducing the cost of developing new therapies is essential to ensure broader access to their benefits without waiting for more affordable generic versions (Hoque et al., 2023).

Data analytics plays a vital role in modern healthcare by enabling policymakers, researchers, and healthcare providers to leverage large volumes of information effectively. Through the collection, processing, and interpretation of diverse data sources, it generates strategic insights into population health trends, resource efficiency, and service quality (Afrihyia et al., 2024). Initiatives such as the Medicaid expansion under the Affordable Care Act have enhanced access to healthcare services, contributing to improved population health outcomes and lower mortality rates. By expanding healthcare accessibility, these policies play a key role in reducing health inequities and promoting the sustainability of healthcare systems through efforts that address the underlying causes of health disparities. Sustainability-oriented policies encourage healthcare institutions to implement energy efficiency measures, reduce waste, and transition to renewable energy sources, ultimately resulting in substantial cost savings. These economic benefits can be reinvested to enhance service quality and strengthen sustainability programs, creating a continuous cycle of improvement within the healthcare system (Behera et al., 2024).

The issue of medical device sustainability has become a significant concern, encompassing aspects of material properties, quality, and performance, as well as the ethical responsibilities of manufacturers and healthcare providers. Moreover, energy efficiency, resource utilization, and commitment to patient well-being reflect the complex demands of modern medical devices while simultaneously opening opportunities for sustainable technological and therapeutic innovation (Vienken & Boccato, 2024). The Netherlands has made significant progress in implementing sustainability principles in the healthcare sector through green procurement policies that ensure medical supplies and equipment are sourced in an environmentally friendly manner. Hospitals in the country also lead in innovative medical waste management, including safe disposal and effective recycling programs. These efforts not only minimize environmental impact but also foster a culture of sustainability within the healthcare system, positioning the Netherlands as a pioneer in ecology-oriented nursing practices (Shaban et al., 2024).

3.5 Indonesia readiness for sustainable health system

Amid the currents of globalization, the dynamics of global health are becoming increasingly complex, requiring countries around the world, including Indonesia, to respond more effectively to demographic changes, shifting disease patterns, and evolving healthcare needs. In addressing these challenges, Indonesia has implemented a health service transformation policy designed to develop a more adaptive and responsive healthcare system. The Indonesian government has enacted Law Number 17 of 2023 on Health as a legal foundation for strengthening the provision of healthcare services at all levels. This initiative also reflects Indonesia's commitment to adapting to various global health challenges. The regulation reinforces six key pillars of the national health transformation: primary healthcare services, referral systems, health system resilience, health financing, healthcare human resources, and health technology (Setiaasih et al., 2025).

When distance becomes a major barrier in healthcare delivery, information and communication technologies can now be utilized to enable the exchange of accurate information. These technologies are applied in the processes of diagnosis, treatment, and prevention of diseases and injuries, as well as in supporting research, evaluation, and continuous learning for healthcare professionals, all with the aim of improving the health quality of individuals and communities (Business et al., 2024). In developing countries, telepharmacy has emerged as an important solution for improving access to healthcare services, particularly in remote and underserved areas. The extent of its implementation varies, with some countries achieving notable progress while others remain behind due to infrastructural and financial limitations. In many cases, the adoption of telepharmacy faces challenges such as limited internet connectivity, inadequate technological support, and insufficient training for healthcare professionals (Ghozali, 2024).

The presence of adequate infrastructure serves as a crucial foundation for a country's development, as it can stimulate various opportunities such as increased employment, reduced poverty and income inequality, and strengthened economic growth (Setyadi, 2021). Healthcare professionals in Indonesia receive their education through a combination of public and private training institutions, with private institutions accounting for approximately 80% of total graduates. The number of healthcare workers has continued to increase, enabling Indonesia to move beyond a critical shortage; in fact, the production of nurses has now exceeded the absorption capacity of the healthcare system. On the other hand, the production of physicians particularly specialists remains insufficient to meet national needs, resulting in persistent shortages even in areas that are generally considered more attractive to healthcare professionals. Another major challenge is the unequal distribution of healthcare workers across regions, as most medical personnel prefer to work on Java Island, especially in major cities. Consequently, a surplus of nurses has led to unemployment in some areas, while many healthcare facilities in rural regions continue to face shortages. Moreover, low compensation and suboptimal working conditions in the public sector have contributed to a shift of healthcare workers toward private-sector employment. To address these issues, the government continues to work on improving the attractiveness of public healthcare facilities particularly in rural areas and expanding access to medical education (Sax et al., 2024).

4. Conclusions

This study highlights the crucial role of public policy and medical innovation based on biodegradable materials in achieving a sustainable healthcare system. Policies that support the use of biomaterials such as PLA, PCL, and magnesium-based composites have been shown to reduce environmental impacts, improve resource efficiency, and strengthen healthcare system resilience. These innovations also drive advancements in biomedical engineering and align with global sustainability goals by reducing medical waste and dependence on conventional plastics. In addition, strong government policies and regulatory frameworks including sustainable procurement systems and targeted R&D incentives play a key role in driving healthcare industry transformation. Case studies from the European Union, the United States, China, and Japan demonstrate that integrated and collaborative policy approaches can accelerate innovation while maintaining safety, quality, and accessibility standards in healthcare services.

Sustainability-oriented policies further encourage healthcare facilities to improve energy efficiency, reduce waste, and adopt renewable energy sources, generating both environmental and economic benefits. The resulting cost savings can then be reinvested to enhance service quality and support continuous improvement within the healthcare system. Achieving a sustainable and equitable healthcare system requires collaboration among governments, researchers, industry, and healthcare providers. With consistent policy support, investment in green technologies, and the integration of biodegradable innovations, the healthcare sector can transform into a more resilient, environmentally friendly, and inclusive system, ensuring better health outcomes for both people and the planet.

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We encourage all authors of articles published in this journal to share their research data. This section provides details on where the data supporting the reported results can be found, including links to publicly archived datasets analyzed or generated during the study. A statement is still required when no new data is created or when data is unavailable due to privacy or ethical restrictions.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the author(s) used Grammarly to assist in improving the grammar, clarity, and academic tone of the manuscript. After using this tool, the author(s) reviewed and edited the content as needed and took full responsibility for the publication's content.

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