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Pharmaceutical Industry Role in Achieving Global Sustainability Goals

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Abstract

Sustainable Pharmacy prioritizes health equity for present and future generations by incorporating sustainable development into pharmaceutical sciences. It tackles the systemic underlying causes of disease through education, the environment, society, the economy, pharmacology, and culture, which is different from Green Pharmacy's ecological focus. It promotes preventative, easily accessible healthcare, and high-impact initiatives to remove obstacles to wellbeing by putting an emphasis on systems thinking. This all-encompassing strategy opposes greenwashing and promotes moral introspection and cross-sector cooperation to guarantee long-term, just health results worldwide. "Good Health and Well-Being," the third Sustainable Development Goal (SDG) of the UN, emphasizes the vital role that drugs play in healthcare. However, there are serious environmental dangers associated with pharmaceutical waste and pollutants of increasing concern (CEC) from the manufacture, use, and disposal of drugs. Even while the sector is implementing sustainable practices like partnerships, enhanced supply chains, and green production, more needs to be done. These include switching to renewable energy, utilizing AI for effective and environmentally friendly resource utilization, establishing a circular economy (based on the 4Rs: reduce, recycle, reuse, recover), and encouraging research for environmentally sustainable solutions. All parties involved must work together to create a sustainable pharmaceutical sector, but there are significant long-term advantages for the industry, society, and environment.

Kyewords: *Pharmaceutical industry; Sustainability; Health; Sustainable development; Medical waste disposal; Environment*

Introduction

In order to eradicate poverty and inequality, advance world peace and prosperity, and make the environment safer for all living things by the end of 2030, the United Nations established the idea of sustainable development goals, or SDGs, in 2015(1). A total of 247 indicators were included with 169 targets from the 17 Sustainable Development Goals (SDGs), commonly referred to as global goals, in order to track the goal's development [1,2]. One of them, "Good health and well-being" (SDG3), is to guarantee healthy lifestyles and advance wellbeing for people of all ages. Pharmaceuticals have a significant impact on people's health and wellbeing. Under Corporate Social Responsibility (CSR), a number of pharmaceutical businesses are spearheading the sustainability agenda and reporting their sustainability efforts in relation to the 17 Sustainable Development Goals (SDGs) [3]. To investigate how drugs affect the environment, allied fields like eco pharmacovigilance have emerged in recent years. To further steer SDG3, the effects of pharmaceuticals on the environment are first assessed in an effort to protect it, and then the data is utilized to establish or alter common behaviours [4,5]. This review article discusses the need for sustainable and safe pharma, its current status, domains of sustainable pharmacy, research gap and challenges for sustainability in the pharmacy, various path to improvement and a vision with futuristic methods.

Need

Chemicals, pharmaceuticals, and personal care products (PCP) are frequently utilized in medical facilities, animal husbandry, and agriculture [6,7]. Any product, including biologics and vaccines, materials, or chemicals produced throughout the course of pharmaceutical manufacturing and use is considered pharmaceutical waste.

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Pharmaceutical products that have been thrown away, unused, or expired are also included [8,9]. An important related word is Contaminants of Emerging Concern (CECs). CECs are the poisons and chemicals present in water bodies that are not currently regulated but have the potential to affect human health or the environment. Pharmaceuticals and personal care items containing cyanotoxins, nanoparticles, and flame retardants are the most prevalent kinds of CECs [10]. A range of waste items, including solvent residues, chemical intermediates, by-products, and contaminated equipment, may be produced throughout the pharmaceutical manufacturing procedures. Additionally, waste is produced during the acquisition, distribution, management, and disposal of raw materials [11]. Depending on whether the waste is hazardous or not, the several procedures depicted in Figure 1 are typically used to dispose of the pharmaceutical waste generated [12]. Pharmaceutical waste can leak into the environment and present serious health and safety hazards to people and other animals when it is disposed of in ways like flushing into the drain, landfills, and free-flowing with or without treatment. Researchers calculated the levels of pharmaceuticals in the environment (PiE) and the public supplies of food, drinking and tap water, groundwater, and surface water. Around 631 medications and their metabolites have been found in aquatic habitats globally, according to a study published in the journal "Environmental Science & Technology" [13]. Similarly, a different worldwide study discovered that 258 rivers have pharmaceutical residues, reflecting the environmental impact on 471.4 million individuals across 137 distinct geographic regions. 1,052 locations in 104 countries provided samples [14]. Pharmaceutical chemicals have also been found in the Arctic, proving that it is not restricted to any one region or nation. These products have an impact on aquatic systems once they enter water bodies because of their active chemical makeup, converted products, or buildup in aquatic plants and animals.

Fish and other wildlife may suffer as a result of pharmaceutical waste that is high in organic materials, such as acetone and alcohols used as solvents, which deplete oxygen and cause eutrophication, or the blooming of algae. In a similar vein, hormonal imbalance, immunological disruption, and even the development of resistant bacteria is brought on by the presence of active pharmaceutical ingredients (API) in wastewater [15].

Current Status

Concerned about the anticipated repercussions of possible negative impacts on the environment, both on land and in water, the pharmaceutical sector is putting more emphasis on sustainability due to legal mandates and environmental accountability. Some of the methods used in the sector include the following:

1. Dedication to green technologies and net-zero carbon footprints:

Pharmaceutical businesses are committed to achieving net-zero carbon footprints, which are defined as carbon emissions leaving a minimal number of leftover emissions that the environment can absorb and manage, as well as additional carbon dioxide removal steps, leaving zero in the atmosphere) by implementing sustainable manufacturing and medication development methods. These include minimizing waste, cutting back on energy use, and investing in green technologies. This duty is supported by a study conducted on 20 major pharmaceutical corporations [16].

2. Integration of AI and cutting-edge technologies: Businesses are using AI and cutting-edge technologies to optimize their manufacturing processes, which lowers waste and boosts energy efficiency. By offering early warnings about possible disruptions, AI is also helping to improve supply chain management and mitigate drug shortages [17,18].

3. Good manufacturing practice (GMP) in the pharmaceutical industry: GMP addresses five essential elements—products, people, processes, procedures, and premises—to guarantee the consistency and quality of a product.

GMP adherence has several benefits, including increased profitability, productivity, and risk reduction, all of which support sustainability [19].

4. Partnerships and collaborations:

The pharmaceutical supply chain involves contract development and manufacturing organizations (CDMOs). Working together with CDMOs facilitates the integration of sustainable manufacturing practices and green initiatives. Implementing energy-efficient production and responsible sourcing requires this collaboration [20].

5. Employee-led initiatives and accountability:

Inter-industry partnerships and employee-led sustainability projects are growing in popularity. Some businesses have made environmental sustainability a medium-term priority.

6.Regulations:

Periodically, regulatory bodies and other stakeholders throughout the world have created and embraced a number of policies, rules, and initiatives pertaining to sustainable development [21,22]. European nations have already adopted the idea of SDG 3 as part of their "Health care without harm" or "Safer pharma campaign" in 2016 [23]. In addition to the Sustainable Development Goals (SDGs) of the UN, which are a set of guiding guidelines pertaining to all facets of development, ISO 14000 Standards offer businesses and organizations useful tools for managing their environmental obligations. Likewise, the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) created the GHG Protocol, which offers extensive worldwide defined frameworks for managing and measuring GHG emissions. As part of the Paris Agreement, various nations and areas also presented their Nationally Determined Contributions (NDCs) outlining their strategies to lower national emissions and advance the SDGs. The Clean Air Act (USA), the Renewable Energy Directive (EU), the Environment Protection and Biodiversity Conservation Act (Australia), Japan's Basic Environment Law, the Climate Change Act in the UK, Germany's Climate Protection Law, India's National Action Plan on Climate Change (NAPCC), and California's Clean Energy and Pollution Reduction Act are a few examples [21,23].

Lastly, "Earth Day" and "World Environment Day" are observed yearly on April 22 and June 5, respectively, to raise awareness of environmental protection. Leaders from industry, government, and civil society come together in New York City for "Climate Week NYC," an event that highlights climate action and solutions [22,23]. Therefore, the various strategies and a

coordinated worldwide effort to accomplish sustainable development goals and guarantee a healthy planet for future generations are reflected in these policies, initiatives, awareness campaigns, and legislation.

Domains of Sustainable Pharmacy

Without claiming to be exhaustive, we suggest that the following six areas—education, environment, society, economy, pharmacology, and culture—are essential to include into the idea of sustainable pharmacy. Every domain offers a viewpoint on various pharmacy-related subjects. They should not be viewed as categorically distinct or independent categories, but rather as a whole. Because their interaction—rather than just their sum—represents a route to greater sustainability, they are consequently equally significant. We use the picture of an aromatic ring to demonstrate this. In contrast to typical single or double bonds, all C–C bonds are equal in length, strength, and importance. Additionally, the electrons are delocalized, resulting in aromaticity, which is distinct from merely taking the sum of the components into account. The introductions to each domain that follow are representative and not exhaustive [24].

Educational domain

A significant worldwide issue, disparities in mortality and life expectancy are categorized by socioeconomic category. Higher educated persons tend to live longer than those with less education. Men and women may differ by up to 8.2 and 4.5 years, respectively. Low income, few social contacts, smoking, heavy alcohol use, obesity, low physical activity, and a diet low in fruits and vegetables are some of the risk factors that make up the disparities in life expectancy and that, with a few exceptions, are more noticeable in those with less education. Since the majority of risk variables can only contribute somewhat on an individual basis, it is advised to take steps that address numerous factors at once in order to significantly lower risk. It is the responsibility of universities to prepare students and future stakeholders in the health care system for the complexity of health care. A systems thinking approach to healthcare or pharmaceutical sciences and practice, as well as environmental implications of pharmaceuticals, have not been widely included in pharmacy courses up to this point. Universities can tackle the topic of sustainable pharmacy in a variety of ways. We view the evolution of sustainable pharmacy as a continuous process, with academics serving as a major catalyst. In the pharmacy degree program's "Ethics and Sustainability" module and, on a more transdisciplinary level, in the lecture series "Academia meets Industry – a Political Scientific Discussion," we at the University of Freiburg discuss a number of sustainability, systems thinking, and ethical issues. We have established a series of Summer Schools on Sustainable Pharmacy at the graduate level in collaboration with others [24].

Environmental domain

The "Anthropocene," when humans dominate Earth's biophysical conditions, is causing biodiversity loss, climate change, and pollution of the air, water, and soil. claimed recently that immediate action is required to minimize harm since the safe operating space of the planetary border for novel entities has been exceeded. According to 2016 research by the United Nations Environment Programme (UNEP) titled "Healthy environment, healthy people," environmental degradation's negative effects on human health account for 23% of all fatalities globally. Diseases like diarrhoea, asthma, malaria, injuries, lower respiratory tract infections, chronic obstructive pulmonary diseases, cardiovascular diseases, cancer, and musculoskeletal disorders have the highest preventable disease burden (measured in disability-adjusted life years) as a result of environmental risks. In these situations, rather than addressing the root causes of the diseases, medications are utilized as a "end-of-pipe" method to cure and alleviate people's avoidable illnesses. Globally, the national carbon footprint of healthcare in 2014 varied from 4 to 8%; for instance, it was 7% in Germany and 8% in the US. The persistence of several medications and transformation products in the environment, as well as their uncertain fate and effects, increase this risk, particularly in light of the environment's varied and unpredictable cocktail. In order to solve this issue, strategies like the circular economy or green pharmacy are employed to reduce waste for medications that cannot be prevented by effective non-medical treatment or preventive [24].

Pharmacological domain

Enhancing bioavailability is one way to lessen the amount of drug released into the environment and to lessen negative human and environmental side effects. Oral bioavailability depends on a number of physicochemical and physiological phenomena, including release from matrices, solubility in gastrointestinal fluids, interaction with gastrointestinal components, chemical degradation or metabolism, and epithelial cell permeability. A medicinal product is a substance or combination of substances intended to treat, prevent, diagnose, or restore physiological functions by exerting a pharmacological, immunological, or metabolic action. Many medications' relatively low or extremely variable bioavailability limits their effectiveness. This raises the possibility of negative side effects in comparison to the intended impact because of an improper medication concentration. Large quantities of medications with low bioavailability stay in the gastrointestinal system, increasing the amount needed for oral delivery and the proportion of the drug and its metabolites that are expelled from the body into the environment. A variety of approaches, including the creation of prodrugs or enabling formulations for contemporary delivery systems, are being sought to address low or highly variable medication bioavailability. We urge careful consideration and differentiation in this area and highlight the application of biomarkers and bioinformatics to promote precision medicine as one of their sustainability principles applicable in drug research. The current issues are more with data management, integration, analysis, and interpretation than they are with technological advancements in data generation (genomics, transcriptomics, proteomics, epigenomics, etc.). Personalized treatment might only be available to affluent people and nations due to the high cost of creating and managing these data. Prioritizing individual health over group health may exacerbate the health disparity and impede sustainable development [24].

Cultural domain

A society's culture includes the principles and goals that underpin its shared way of life, as well as the methods and outcomes of how these principles and goals are expressed in society. explains further that through cultural activity, we (1)

establish common ways to communicate our wants and ideals, (2) make meaning of our existence and the environment we live in, and (3) overcome the obstacles presented by our ongoing responsibility to the world. The identification of key values, evaluation of the past and how pharmaceutical thinking and action connect with these values, discussion of the future, and present-day action are all aided by a cultural perspective on the pharmaceutical sciences. Pharmaceutical goods and services, as well as the healthcare system, must be founded on their advantages for individuals and society in order to "make sense." The following fundamental principles are assumed for additional debate in the context of Sustainable Pharmacy: diversity, equity, justice, self-determination, and health. The fact that there is no common definition for the concept of health is one of the numerous difficulties. In its preamble to the Constitution, the WHO states that "health is a state of complete physical, mental, and social wellbeing and not merely the absence of disease or infirmity," as covered in Section 4. Promoting knowledge and conversation about the distinctions between "health" and "illness" is one strategy for cultural activism. This could serve as a platform for debate regarding the difficulties in articulating and advancing these ideals as well as aid in illuminating the ethical and social ramifications for society and the pharmaceutical sciences [24].

Societal domain

Examined from the standpoint of individual and group behaviour as well as the social systems that exist between them, this viewpoint covers the societal ramifications and pharmacy operations pertaining to the therapeutic and non-therapeutic use of pharmaceutical preparations. A society, its health, and the healthcare system are more than the sum of its members, according to a systems thinking approach. Important elements include how each person interacts with the system and its purpose or objective. Providing health information and guidance on the safe and sensible use of medications is part of the pharmacist's job description. It's critical to comprehend the socio-behavioural facets of medicine use in order to attain the best possible therapeutic results. For patients, society, medical professionals, and legislators, the pharmacist serves as a low-threshold interface and point of contact. "Polypharmacy" is another significant issue in an aging society. This is the usage of several drugs as a result of multimorbidity, particularly in older people. Polypharmacy raises the possibility of unfavourable side effects or lessens the therapeutic benefit of some drugs. The social viewpoint emphasizes the necessity for pharmacists to take on creative patient-focused positions, like drug analysis and adherence counselling, and to spend more time with patients rather than goods [24].

Research Gaps and Challenges for Sustainability in the Pharmaceutical Industry

Our analysis of the state of sustainability research in the pharmaceutical sector shows that social sustainability has received little attention. The analysis primarily showed that the focus of such studies is environmental sustainability, primarily in terms of cleaner production, green supply chain, green materials, and sustainable HRM, even though the literature review indicated that management studies are permeable to the issue of sustainability of the pharmaceutical industry. Nonetheless, it seems clear that there is some fragmentation and a lack of consensus around the main topics. The literature assessment specifically points to a disregard for social sustainability. This is very unexpected considering the pharmaceutical industry's acknowledged contribution to societal well-being. The need for more widespread adoption of "healthy lives" for everyone, as outlined, for instance, in the declarations of global organizations like the United Nations, appears to be less developed in the literature. Regarding potential topics for further study, we pinpoint a few issues that the systematic literature review's findings raise. The relationship between developed and emerging markets is the subject of another emerging gap that is partially related to the preceding one. The focus on emerging markets mostly pertains to the manufacturing of pharmaceuticals by domestic firms or subsidiaries of multinational corporations, including but one aspect of pharmaceutical production worldwide. In actuality, there is a concentration of production in some mature countries that appears to be overlooked in the literature, even while emerging markets account for a sizable portion of global drug manufacturing (for example, India is the world's largest producer of generic pharmaceuticals). The connection between innovation and sustainability is another area that receives little attention. On the one hand, the empirical data indicates a shift in the technological direction toward investigation and the creation of costly compounds that have the potential to revolutionize certain illnesses. Cases like the recent May 2019 introduction of a pharmaceutical treatment for gene therapy of spinal muscular atrophy (SMA), which costs 2.1 million dollars per patient and has been approved by the Food and Drug Administration, present significant sustainability challenges. The average life expectancy has increased above 80 in industrialized nations, while advances in medical research, pharmaceuticals, and technology have raised living standards. Despite being undeniably desired, these factors come at a cost to the healthcare system. As a result, the focus is on the economic aspect of sustainability and the connection between sustainable pharmaceutical firms and sustainable health systems [25].

Path to Improvement

Redefining the role of governments in the innovation ecosystem.

The broad conditions (infrastructure, services, tax laws, etc.) that enable entrepreneurs and inventors to release the force of science into technological advances are generally understood to be the responsibility of the government. This point of view holds that governments cover the gaps left by the private sector, such as funding research. According to this school of thought, governments play a passive role in the development of novel solutions and are entitled to benefits when things go well because they are the private stakeholders who bear the majority of the risk. The government's strategy is being questioned because the private sector often makes investments after the state has made the riskier ones, and enormous amounts of public funds are allocated to health innovation [26]. However, oversimplified perspectives on winners and losers that result in catchphrases like "while risks are socialized, profits are privatized" ought to be avoided.

Governments ought to get a larger portion of the advantages of biomedical advances, regardless of the specifics of how they should be allocated. Public measures that seek to rectify or balance the distortions of the current system—which is primarily run by pharmaceutical companies—should be implemented using those resources. Governments should use these resources to:

1. Conduct their own drug development initiatives with an emphasis on social rather than financial gain.
2. Put preventative and early detection initiatives into action.
3. Fund research and development initiatives on neglected illnesses and environmentally friendly methods of creating novel medications.

Drug repurposing and licensing of shelved drugs.

Researching new uses for approved, experimental, or abandoned medications is known as drug repurposing. This might reduce development times by 6–7 years and overall expenditures to $300 million, as opposed to an estimated $2–3 billion for a new chemical entity [27]. The difficulties in patenting a new repurposed indication and upholding patent rights, as well as a lack of initiative on the part of companies that own drugs with repurposing potential (focusing on the original application and resisting out-licensing), are the main reasons why the potential of drug repurposing is still largely unrealized. Despite the fact that pharmaceutical companies typically patent novel treatments, they are shelved after additional research and development stops. Ninety percent of clinical medication developments are thought to be shelved [28]. There are a lot of chances to create less expensive medications through pharmacological repurposing and reactivation of shelved assets. Policies should focus on the following to encourage these areas:

1. Create innovative IP regulations to facilitate the protection of repurposed medications.
2. Establish policies for repurposed and shelved medications, such as the Orphan Drug Act
3. Encourage the out-licensing of medications that have been put on hold by lowering taxes or taking other comparable measures
4. Establishment of government or spin-off medical development programs and an investment ecosystem cantered on repurposed and shelved medications.

Natural products.

The production of chemicals and solvents from coal and oil will probably decline in the future, making synthetic medications unreliable in the long run. Furthermore, downstream production sites and the environment after patient usage may be impacted by active pharmaceutical ingredients (APIs) [29]. A sustainable alternative to synthetic medications is natural goods. They are chemical entities created by naturally existing living organisms; such as plants, algae, bacteria, and yeast; with medicinal qualities. Pharmaceutical companies have scaled back their natural product-based drug discovery programs despite the environmental and chemical benefits and numerous successful examples. This is primarily because natural products present unique technical and intellectual property challenges [30]. Sustainable methods for industrial-scale natural product isolation and production include in situ extraction using green solvents like glycerol or natural deep eutectic and ionic solvents (NADES) [31]. Natural products as a source of new APIs are an opportunity for more sustainable and cheaper drugs, representing a strong rationale for the preservation of biodiversity and allowing countries to use it for wealth creation. Policies should focus on the following to encourage these areas:

1. Develop unique IP policies to ease the protection of natural products.
2. Simply the Nagoya protocol.
3. Encourage the establishment of government or spin-off drug development initiatives and a natural product-focused investment environment.

Sustainable Pharma: A Vision and a Mission

The goal of sustainable pharma is to have the pharmaceutical sector function in a way that strikes a balance between environmental stewardship, social responsibility, and economic growth. This is a thorough plan for sustainable pharmaceuticals:
Green chemistry and sustainable manufacturing Designing chemical products and procedures that minimize or completely do away with the usage and production of hazardous materials is known as "green chemistry." This implies the following for the pharmaceutical industry: environmentally friendly procedures: create production methods that employ renewable resources, cut down on waste, and use less energy; Solvent reduction: minimizing environmental contamination by employing solvent-free or more environmentally friendly techniques;

Efficient synthesis is the process of creating synthetic pathways that minimize waste and raw material consumption by maximizing atom economy and reducing the number of stages [32].

Circular economy

Reduce, Reuse, Recycle, and Recover are the four pillars of the circular economy. It entails creating and manufacturing goods and procedures as well as using them in a way that minimizes waste and makes use of recycled or repurposed materials. As much as feasible, it entails sharing, renting, reusing, repairing, renovating, and recycling already-existing materials and goods. A closed-loop system is a component of the circular economy in which waste from one process is used as input for another, lowering total waste. But the circular economy isn't always economical [33].

Energy efficiency and renewable energy

The pharmaceutical sector uses a lot of energy.
Sustainable pharmaceutical aims to create energy-efficient facilities by building and renovating buildings with LED lighting, high-efficiency HVAC (heating, ventilation, and air conditioning) systems, and intelligent energy management systems; Renewable energy: switching production facilities and research centres to renewable energy sources like solar, wind, and geothermal; Reducing carbon emissions: putting policies in place to lower greenhouse gas emissions throughout the supply chain to less than 2 °C, and ideally no more than 1.5 °C [32].

Sustainable supply chain

From acquiring raw materials to distributing products, a sustainable supply chain makes sure that all processes follow sustainability guidelines. Purchasing raw materials from vendors who follow ethical and sustainable procedures is known as ethical sourcing; Local production: producing goods nearer to the consumer in order to boost regional economies and cut down on transportation-related pollution; Green logistics includes carbon offset schemes, delivery route optimization, and the use of environmentally friendly modes of transportation [34].

Research and development (R&D)

The goal of sustainable R&D is to create medications that are not only efficient but also economical, useful, and environmentally friendly:

29 Drug design that is environmentally friendly: creating biodegradable medications will have little effect on ecosystems; alternatives to animal testing, such as reducing the need for animal testing through the use of cutting-edge technology like organ-on-chip and computer modelling; Sustainable discovery platforms: employing synthetic biology and biotechnology to find new medications in a more environmentally friendly way [33,35].

Social responsibility and community engagement

Sustainable pharmaceutical encompasses social responsibilities in addition to environmental concerns. Access to medications: guaranteeing that everyone, especially in low- and middle-income nations, has inexpensive access to necessary medications; initiatives related to community health: funding, participating in, and volunteering for community health programs and education to enhance public health results; Fair labor practices: maintaining ethical labour standards and guaranteeing secure working conditions across the supply chain; educating the general public on appropriate use and disposal [33,34,35].

Policy and regulatory compliance

Collaboration with regulatory bodies to develop and implement sustainability standards and guidelines is necessary because research has demonstrated that controls, legitimacy, and deterrence have a greater impact than social norms and values, particularly in small and medium-sized entrepreneurial ventures when addressing sustainability during manufacturing; Transparency and reporting: keeping sustainability practices transparent and providing frequent updates on the state of sustainability objectives; Advocacy: promoting laws that uphold social justice, public health, and environmental preservation in the pharmaceutical industry; Encouragement to adopt eco-friendly technologies [35,36].

Innovation and continuous improvement

The process of sustainability necessitates constant innovation and advancement. Promoting innovation in sustainable practices through R&D expenditures, collaborations with academic institutions, and open innovation platforms is known as sustainable innovation; Monitoring and assessment: consistently keeping an eye on sustainability performance and implementing data-driven strategies to make ongoing enhancements; Stakeholder involvement is the process of working together on projects and coordinating on sustainability goals with stakeholders including as staff, patients, regulators, and the community [37].

Conclusion

Academic study on the sustainability of the pharmaceutical sector is still lacking, especially when considering company behaviour from a management standpoint. Despite the growing interest in sustainability, the literature currently in publication lacks a coherent overview and frequently focuses on discrete elements or real-world examples rather than comprehensive insights. This dispersion is highlighted in a new review, which also identifies five important research gaps. Notably, a number of gaps relate to the issues of cleaner manufacturing, such as the management of pharmaceutical waste, the growth of sustainable production in developed markets, and the financial effects of implementing cleaner methods. To promote industry change and raise the standard of living worldwide, these topics urgently need scholarly attention. The study also emphasizes the necessity of looking into how sustainability and ethical aspects, such corporate social responsibility (CSR) and business ethics, connect. Future studies should examine how pharmaceutical firms incorporate sustainability into stakeholder involvement and moral decision-making. The study intends to assist academics in tackling important sustainability issues in the field by organizing existing knowledge and highlighting these gaps, thereby fostering a more ethical and sustainable pharmaceutical industry for coming generations.

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Conflicts of interest

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