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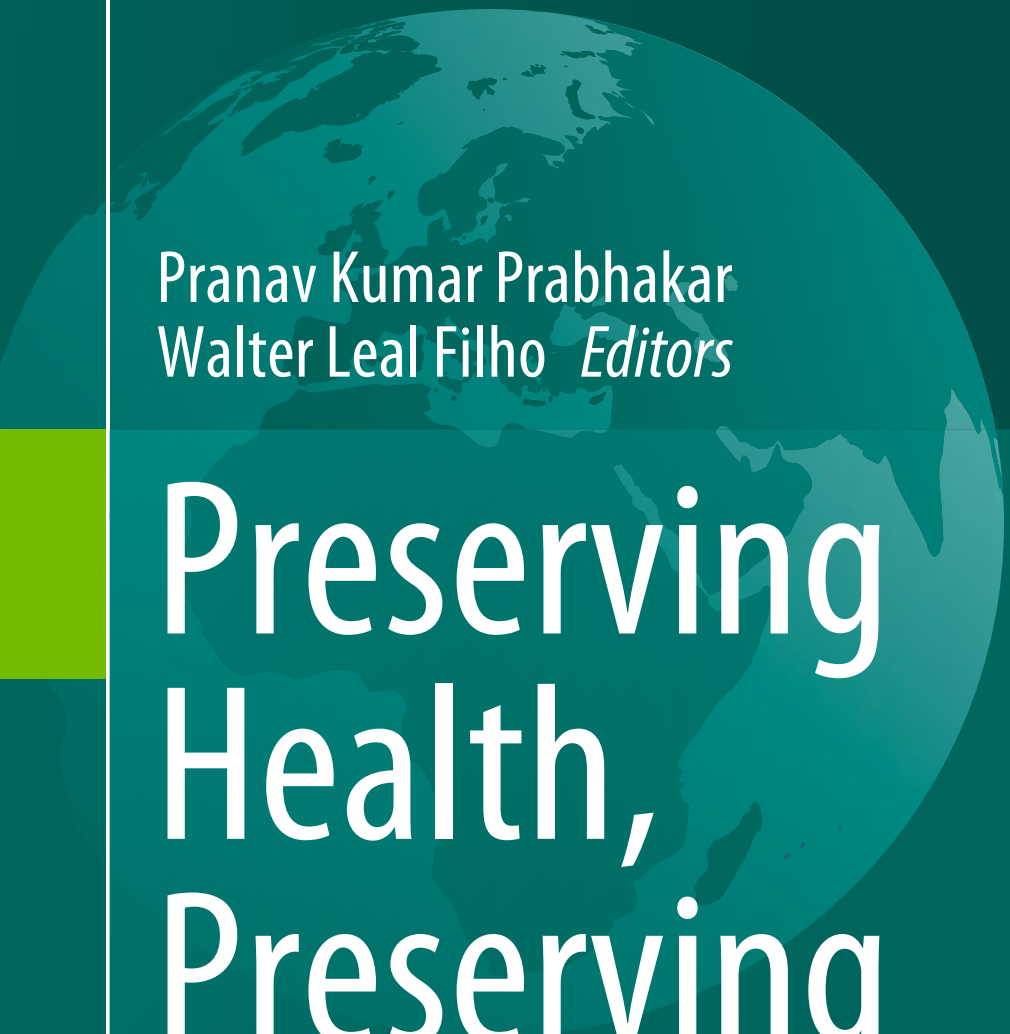

Pranav Kumar Prabhakar
Walter Leal Filho *Editors*

Preserving Health, Preserving Earth

The Path to Sustainable Healthcare

Springer

World Sustainability Series

Series Editor

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Due to its scope and nature, sustainable development is a matter which is very interdisciplinary, and draws from knowledge and inputs from the social sciences and environmental sciences on the one hand, but also from physical sciences and arts on the other. As such, there is a perceived need to foster integrative approaches, whereby the combination of inputs from various fields may contribute to a better understanding of what sustainability is, and means to people. But despite the need for and the relevance of integrative approaches towards sustainable development, there is a paucity of literature which address matters related to sustainability in an integrated way.

Notes on the quality assurance and peer review of this publication

Prior to publication, the works published in this book are initially assessed and reviewed by an in-house editor. If suitable for publication, manuscripts are sent for further review, which includes a combined effort by the editorial board and appointed subject experts, who provide independent peer-review. The feedback obtained in this way was communicated to authors, and with manuscripts checked upon return before finally accepted. The peer-reviewed nature of the books in the "World Sustainability Series" means that contributions to them have, over many years, been officially accepted for tenure and promotion purposes.

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Preface

In an era defined by unprecedented environmental challenges and a growing awareness of the interconnectedness of human health and planetary well-being, the need for sustainable healthcare solutions has never been more urgent. The edited volume you hold in your hands, *Preserving Health, Preserving Earth: The Path to Sustainable Healthcare*, emerges as a beacon of hope and a call to action in navigating the complex intersection of health preservation and environmental stewardship.

This book represents a collaborative effort by leading experts and scholars from diverse fields, each offering unique insights and perspectives on the pressing issues facing modern healthcare systems. Through a multidisciplinary lens, the chapters delve into the intricate relationships between human health, environmental degradation, and the imperative for sustainable healthcare practices. As we confront the dual challenges of environmental degradation and the increasing burden of disease, it becomes abundantly clear that the health of our planet is intimately intertwined with the well-being of humanity. From the impacts of climate change on public health to the pollution of air, water, and soil, the chapters in this volume elucidate the myriad ways in which environmental factors shape our health outcomes. Yet, amidst these challenges, there exists a beacon of hope—a path forward toward sustainable healthcare practices that prioritize the health of both individuals and the planet. Through the exploration of renewable energy solutions, the promotion of green infrastructure in healthcare facilities, and the advocacy for policy reforms, this book charts a course toward a more resilient and equitable healthcare future.

We extend our deepest gratitude to the esteemed contributors who have lent their expertise and insights to this volume. Their dedication to advancing the dialogue on sustainable healthcare is reflected in the richness and depth of the chapters presented herein. To the readers—whether scholars, practitioners, policymakers, or concerned citizens—we invite you to engage with the ideas and proposals put forth in these pages.

Ultimately, *Preserving Health, Preserving Earth* serves as a testament to the collective resolve to safeguard both human health and the planet we call home. May this book inspire dialogue, spark innovation, and catalyze meaningful action toward

a future where healthcare is not only accessible and equitable but also sustainable for generations to come.

With an unwavering commitment to the preservation of health and the Earth.

Phagwara, India — Pranav Kumar Prabhakar
Hamburg, Germany — Walter Leal Filho

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Confronting the Health Impacts of Climate Change: A Comprehensive Exploration

Aniruddha Sen and Ayan Chatterjee

Abstract This review article extensively explores the intricate correlation between climate change and its profound effects on human health and well-being. On a global scale, there is an alarming trend of increase in ambient temperatures, erratic weather patterns, and the escalation of greenhouse gas emissions. In the Indian context, a nation highly susceptible to climate shifts, these effects are particularly pronounced due to its varied geography and dense population. The study examined the ramifications of alterations in both indoor and outdoor environments. Changes in climate lead to modified ventilation patterns, compromising indoor air quality. Concurrently, outdoor settings experience elevated levels of air pollution and heightened concentrations of allergenic pollen. These changes have significant health implications, exacerbating conditions such as asthma and contributing to the surge of cardiovascular ailments. Furthermore, the article delves into the challenges faced by individuals compelled to migrate for work, often landing in regions disproportionately affected by climate change. These migrating populations confront amplified health risks due to inadequate living conditions, restricted healthcare access, and exposure to extreme weather occurrences. The review also underscores the intricate interplay between climate change and its consequences on various bodily systems. Heatwaves strain thermoregulation mechanisms, resulting in heat-related illnesses. Vector-borne diseases expand their reach as shifting temperatures create favorable breeding environments for disease-carrying insects. Waterborne diseases surge due to altered precipitation patterns impacting water quality and availability. In conclusion, this comprehensive review underscores the urgent necessity for action to mitigate the health repercussions of climate change. It advocates for multi-faceted interventions addressing both indoor and outdoor settings, safeguarding susceptible populations, and fostering global collaboration to mitigate the escalating health effects of a changing climate.

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Keywords Thermal modelling · Public health · Mitigation · Adaptation · Mobility

1 Introduction

The robust evidence of global climate change underscores an undeniable and alarming trend of warming temperatures over the past century. Each successive decade since the mid-1800s has demonstrated an unequivocal increase in global temperatures, with the decade from 2011 to 2020 standing out as the warmest ever recorded, surpassing pre-industrial levels by approximately 1.09 °C. This accelerating warming trend is directly linked to the escalating emissions of greenhouse gases, primarily stemming from anthropogenic activities such as the combustion of fossil fuels, deforestation, and intensive agricultural practices (IPCC 2007). The concentration of carbon dioxide in the atmosphere, a key driver of the greenhouse effect, has experienced an exponential surge. Presently exceeding 415 parts per million (ppm), this level is unprecedented in at least 800,000 years (Climate change 2007: the physical science basis 2007). The multifaceted impacts of these climatic shifts extend across ecological stability, infrastructure resilience, global economies, and most critically, human health (Friedlingstein et al. 2022). The Lancet Countdown 2021 report, a comprehensive analysis of climate change and health, provides critical insights supported by a thorough examination of 44 indicators across five key domains (USGCRP 2018).

These domains encompass direct impacts and vulnerabilities related to climate change, adaptation planning, mitigation actions and their public health co-benefits, economic considerations, and political and public engagement. The health implications of climate change are severe, with projections indicating that by 2030–2050, heat exposure, childhood undernutrition, malaria, and other climate-sensitive diseases could lead to over 250,000 additional deaths annually (Xiang et al. 2015). Mental health is also profoundly affected, as individuals grapple with the trauma associated with livelihood losses, forced migration, and community disruptions (Knowlton et al. 2014). Food security is under imminent threat, with estimates suggesting potential average yield losses of 25% for maize, 14% for sorghum, and 10% for millets in India by 2100 (Clayton 2021). The economic toll is substantial, with India projected to lose 5.8% of its GDP by 2100 due to the adverse impacts of climate change. Urgent and substantial actions are imperative to address these challenges. Deep cuts in greenhouse gas emissions, coupled with effective adaptation measures, are crucial not only to avert massive economic losses but also to safeguard the health and well-being of populations. The call for action is reinforced by the urgency to mitigate the profound impacts of climate change on health and well-being. Climate action plans must adopt a holistic approach, considering the health impacts across various economic sectors and vulnerable communities, to ensure a resilient and sustainable future (Venugopal et al. 2016).

2 Climate Change in India

India's diverse geography, encompassing the Himalayan glaciers, arid deserts, fertile plains, coastal regions and island chains, paired with a massive population exceeding 1.38 billion in 2021, renders it highly vulnerable. Multiple climatic changes are transpiring simultaneously across regions. Surface air temperatures have risen around 0.7 °C nationally from 1901 to 2018 (Xiang et al. 2014). The warming spikes further in cities due to the heat island effect—studies in Gujarat recorded over 6 °C higher night temperatures in urban areas. The warming is exacerbated by drastic changes in land use patterns. Forest lands and wetlands are being rapidly converted to agricultural land or urban built-up areas (Mohanty and Mohanty 2017). This change in land surface types significantly impacts energy flux between the land and atmosphere affecting weather patterns. Deforestation in the fragile Himalayan Mountain ecosystems is also triggering rainfall variability and soil erosion. Glacial retreat continues unabated due to warming—by 2050, one-third of the 4,040 Himalayan glaciers could disappear affecting perennial rivers. The monsoon rainfall is disrupted as well—though total rainfall shows no significant trend yet, there is an increase in extreme rainfall events and simultaneous decline in the number of rainy days, severely impacting India's largely rain-fed agriculture. Just 1 °C rise in summer temperatures is projected to lower crop yields of major cereals by 3–7% (Lundgren et al. 2013).

Intensification of tropical cyclones has led to the 2005 Mumbai floods and 2019 Cyclone Fani with wind speeds over 200 km/h (Lucas et al. 2014). Climate change also elevates air pollution levels which already contribute heavily to India's disease burden. In Delhi, higher temperatures over 1998–2018 enhanced particulate matter concentrations combining with local emissions (Cheng et al. 2022). The public health implications are massive—from surged heat-related mortality, changing patterns of vector-borne and water-borne diseases, along with mental health issues associated with livelihood disruptions and migration.

3 Indoor and Outdoor Environmental Changes

Indoor settings are being profoundly impacted by climate change in India. Traditional housing designs incorporated climate-responsive architectural elements like air pockets, open courtyards, induced ventilation and shading (Singh et al. 2011). However, modern buildings have moved towards sealed envelopes reliant on-air conditioning. These buildings have significantly altered indoor ventilation patterns, affecting air quality (Adam-Poupart et al. 2013). Studies reveal over 87% of urban homes exhibit poor ventilation, with concentrations of pollutants like CO_2, particulate matter, volatile organic compounds, and biological contaminants exceeding safe limits (Liang et al. 2019). This heavily impacts health given over 70% of time is spent indoors (Balakrishnan et al. 2011).

Use of biomass cooking fuels also degrades indoor air quality—almost 30% rural and 5% urban households rely on polluting fuels like firewood, dung cakes etc. exacerbating respiratory conditions (Government of India 2018). Outdoor urban air quality is deteriorating rapidly from local emissions coupled with regional climate factors. Over 90% residents breathe air exceeding national safety limits (Dash et al. 2017). Climate change serves to elevate pollution levels further through complex mechanisms. Particulate matter levels spike at higher temperatures as heat intensifies photochemical reactions and increases ground-level ozone. Pollen and mold proliferation also escalates in warmer weather with early onset of flowering cycles, longer pollen seasons, and higher production. Reports indicate allergic rhinitis and asthma hospitalization from pollen allergies are surging. Without urgent mitigating policies for cleaner energy, these synergistic health risks shall continue rising (Adam-Poupart et al. 2013).

4 Health Implications

Climate change serves to exacerbate several health conditions especially for marginalized communities in India. With elevated temperatures, humidity and air pollution levels, cases of heat cramps, heat exhaustion and life-threatening heat strokes are surging (Klepeis et al. 2001). Mortality spikes have been recorded during heatwaves—the 2015 heatwave caused over 2,300 deaths in India (Dhiman et al. 2010). Thermal discomfort is linked to lower worker productivity, performance deficits and occupational injuries (Patel et al. 2011). Respiratory conditions like asthma worsen due to combined exposure to allergens, ozone and particulate matter from weather changes and rising pollution (Bain et al. 2014). Studies indicate over 75% rise in wheezing, breathlessness, and asthma attacks during summer months (Caminade et al. 2019). Asthma hospitalization rates peak following dust storms or extreme precipitation which elevates pollen and mold in the air (Revi 2008).

Cardiovascular mortality and morbidity also escalate during heatwaves as well as following extreme cold events in winter (Borhade 2011). Air pollutants induce systemic inflammation, constrict blood vessels, and disrupt heart rhythms—daily emergency hospitalizations for acute heart attacks surge by around 44% per 10 $\mu g/m^3$ increase in same day PM2.5 levels. India has over 100 million seasonal migrants engaged in informal work. Agricultural distress from climate factors is spurring short-term mobility to urban areas (Ahmadalipour and Moradkhani 2018). However, cities concentrate health risks from heatwaves, disasters, and infections. Inadequate housing, nutrition and exclusion from health services amplify risks for migrants (Liu et al. 2003).

Their hazardous working conditions like in brick kilns, mines or sewers add to the burden. Women and children are especially vulnerable, facing threats of violence, adverse pregnancies, and lack of childcare. Climate change worsens these intersections of poverty, informality, mobility, and environmental risk (Pearson et al. 2010).

5 Complex Interplay with Bodily Systems

Rising temperatures due to climate change directly threaten thermoregulation mechanisms in the human body. Heatwaves are becoming more frequent and intense in urban regions causing thermal stress (Klepeis et al. 2001). Prolonged heat exposure overwhelms the body's cooling system potentially leading to multi-organ dysfunction and death among vulnerable groups like infants, elders, and outdoor workers (Kaur and Pandey 2021). Renal function is disrupted due to blood flow redistribution and dehydration while the gut barrier integrity is compromised permitting leak of endotoxins into blood circulation (Tiwari et al. 2014). The changing climate also enables expansion of vectors like mosquitoes, ticks and flies which transmit infectious diseases (Zhang et al. 2016). Warming allows accelerated vector reproduction rates due to shortened life cycles and expanded seasonal duration (Azhar et al. 2014). Heavy rainfall further offers more stagnant water breeding grounds amplifying populations. Cases of malaria, dengue, chikungunya, Japanese encephalitis, and other vector-borne diseases are rising (Kjellstrom et al. 2016). Similarly, waterborne infections spread due to extreme rainfall events which contaminate drinking water sources. Over half the Indian population faces high to extreme risk of diarrheal diseases due to unsafe water supply which is being further jeopardized by climate variability (Sheffield and Landrigan 2011). Cholera outbreaks in coastal cities are aggravated by warming oceans, higher humidity and floods from sea level rise and storms. Addressing health resilience to climate change necessitates tackling vulnerability to such disease transmission mechanisms (Agarwal et al. 2018).

6 Urgent Necessity for Action

Addressing the escalating public health impacts of climate change in India necessitates urgent multi-faceted interventions. Adaptation policies should encompass strengthening health systems, disease surveillance, resilient infrastructure, disaster preparedness and targeted safeguards for vulnerable groups. Heat action plans implemented in Ahmedabad and other cities incorporating early warning systems, public awareness and infrastructure modifications have demonstrated health benefits. However, intensified mitigation efforts simultaneously remain vital to curb emissions and avert catastrophic impacts projected this century (Wu et al. 2017). The National Action Plan on Climate Change launched in 2008 emphasized efficacy, equity, and environmental sustainability in climate actions across sectors. Visionary initiatives like India's renewable energy commitments, expanding forests through community participation and sustainable agriculture models display home-grown leadership (Roy et al. 2001).

However, realizing their full potential warrants transfer of green technologies and financing from industrialized states responsible for most emissions historically.

Article 4 of the UNFCCC and concept of 'common but differentiated responsibilities' compels such global collaboration, both on mitigation and support for climate change adaptation. Vulnerable low-income countries bear negligible culpability for climate change, but shoulder amplified health, economic and social consequences from business-as-usual. Urgent climate justice demands that polluting nations curb emissions while assisting developing regions build requisite resilience (Rumana et al. 2014).

7 Conclusion

Our comprehensive exploration of the intricate correlation between climate change and its profound effects on human health and well-being emphasizes the urgent necessity for multifaceted interventions. The evidence presented throughout this review underscores the severity of the health implications, with projections indicating alarming increases in heat exposure, childhood undernutrition, and climate-sensitive diseases. Mental health is also profoundly affected, with individuals grappling with the trauma associated with livelihood losses, forced migration, and community disruptions. The specific focus on India, a nation highly vulnerable to climate shifts due to its varied geography and dense population, reveals the multifaceted challenges faced by diverse regions. From the Himalayan glaciers to arid deserts, fertile plains, coastal areas, and island chains, each region experiences unique climate changes with far-reaching health consequences. Surface air temperatures have risen nationally, and the warming spikes further in urban areas due to the heat island effect. Glacial retreat disrupted monsoon patterns, and intensification of tropical cyclones pose significant threats to agriculture, water resources, and public health. Our exploration extends to the intricate interplay between climate change and various bodily systems. Rising temperatures directly threaten thermoregulation mechanisms, leading to heat-related illnesses and multi-organ dysfunction, particularly among vulnerable groups. Vector-borne diseases, including malaria, dengue, and chikungunya, are on the rise due to expanded breeding environments for disease-carrying insects. Waterborne infections escalate with extreme rainfall events, impacting over half of the Indian population facing high to extreme risks of diarrheal diseases. The review delves into the significant changes occurring in both indoor and outdoor environments. Modern buildings with sealed envelopes alter indoor ventilation patterns, resulting in poor air quality, especially in urban areas. Outdoor urban air quality is deteriorating rapidly due to local emissions and climate factors, exacerbating pollution levels, and contributing to respiratory conditions.

The complex interplay of climate change with health extends to the challenges faced by migrating populations, particularly those engaged in informal work, facing hazardous conditions, inadequate housing, and limited healthcare access. Recognizing the escalating public health impacts of climate change, urgent action is imperative. Adaptation policies should encompass strengthening health systems, disease surveillance, resilient infrastructure, disaster preparedness, and targeted safeguards

for vulnerable groups. Heat action plans, incorporating early warning systems, public awareness, and infrastructure modifications, have demonstrated health benefits and should be expanded. Simultaneously, intensified mitigation efforts are vital to curb emissions and avert catastrophic impacts projected for this century.

India's efforts, such as the National Action Plan on Climate Change and visionary initiatives in renewable energy, afforestation, and sustainable agriculture, display home-grown leadership. However, achieving their full potential requires global collaboration, including the transfer of green technologies and financing from historically polluting nations. Climate justice demands that developed nations curb emissions while assisting developing regions in building requisite resilience. In essence, this comprehensive review advocates for immediate and sustained action to mitigate the escalating health effects of climate change. The call to address this global crisis extends beyond national boundaries, requiring collaborative efforts to safeguard the health and well-being of current and future generations.

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Sustainable Practices in the Pharmaceutical Industry: Development and Adoption

Koyel Kar, Sailee Chowdhury, Priyanka Chakraborty, and Arpan Saha

Abstract Recently, organizations, customers, and governments have all begun to pay more attention to the pharmaceutical industry's sustainability. Concerns about integrating sustainability principles into creating new delivery systems, new products with lower environmental risks, waste recycling, reducing water use, eco-friendly manufacturing processes, and recyclable packaging have heightened interest in this subject. Pharmaceutical firms are experiencing a higher level of management complexity as a result of the need to maintain environmental, economic, and social sustainability as well as control costs. This has resulted in integrating economic reasoning into the management of sustainability challenges. The manufacturing environment has altered since the Government of India's Ministry of Environment and Forests first mandated non-financial reporting for corporate organizations in 1993. With most of the activity documented in the last decade, the regulatory framework for examining the environmental effects of chemical-based industrial facilities has been reinforced. The numerous manufacturing processes in pharmaceutical manufacturing facilities require a wide range of chemical syntheses. These procedures take a lot of energy, which results in substantial greenhouse gas emissions and waste production. This chapter explains how pharmaceutical companies are pursuing sustainability while taking into account societal economic and social well-being, environmental concerns, and other factors. The main goal is to provide people with a better knowledge of the sustainability trend that is currently affecting the pharmaceutical manufacturing industry and where it is going. There has been a discussion of the advantages of several strategies for achieving sustainability in pharmaceutical organizations. The readers will better grasp how pharmaceutical settings might adopt various practices to achieve sustainability, what different performance measures are accessible, and how reporting sustainability improves an organization's transparency and efficiency. Thus, with the following objectives in mind, the business and management studies

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that have already been done on sustainability in the pharmaceutical industry have been reviewed.

Keywords Sustainability · Pharmaceutical industry · Sustainable development · Green chemistry · Environmental effects

1 Introduction

The adoption of sustainable practices is on the rise globally across several industrial sectors, according to an assessment of a wider range of literature. It was noted that as socio-ecological problems gain more attention, environmental initiatives are being included in a wider range of corporate strategies for manufacturing companies (Salwa et al. 2008). The aforementioned research concluded that the four main approaches to sustainable manufacturing were material, resource, eco-efficiency, and waste minimization. The relationship between complicated environmental problems and manufacturing processes has been acknowledged since the first UN conference on the environment was held in Stockholm in 1972. The Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs"; this gave rise to the idea. There are two goals this chapter seeks to accomplish. First and foremost, it seeks to improve knowledge of sustainability's development, associated practices, and incorporation into the business models often used in the pharmaceutical industry (Mélanie et al. 2013). The analysis from multiple research studies concluded that businesses are under pressure from stakeholders to demonstrate their accountability, transparency, and effectiveness of governance through corporate sustainability disclosures. It also aims to provide a brief overview of the industry's trends and contributions in light of the current Indian scenario. Consequently, integrating sustainability at the corporate level is a strategic choice that must be made to generate a sufficient level of commitment throughout the entire organization (Sabrina et al. 2016). In the manufacturing sector, if sustainability is the objective, the best way to achieve it is through process innovations or the adoption and integration of existing practices most efficiently. Sustainability in the industrial sector emphasizes the same fundamentals of ecologically friendly goods and services, but how this is accomplished varies depending on the industry. Sustainability may imply different things to the industrial sector than it does to the service sector. According to Paul and Stuart (1995), the environmental challenges of today are a result of the unsustainable industrial activity of the past (Paul and Stuart 1995).

Statistically proving that trade, information exchange, and technological access are the new avenues via which economic globalization is creating prospects for prosperity and improved quality of life. Technology and knowledge advancements are fostering economic growth, but they also hold the potential to mitigate dangers and challenges to the long-term viability of our economies, social structures, and environments. The purpose of this chapter is to provide an understanding of the

severity and urgency of the dangers and challenges to the pharmaceutical industry's collective sustainability. This paper aims to communicate openly and clearly about other major sustainability drivers to a range of stakeholders, regardless of the size and location of the pharmaceutical organization. These drivers include the increasingly available choices and opportunities for investment decisions and research and development (R&D), which are oriented towards green manufacturing. The purpose of this chapter is to provide insight into and raise awareness of the sustainability-related practices and trends in the Indian pharmaceutical business. The findings that have been reported can assist the companies in making necessary adjustments and in producing a fair and impartial portrayal of practices connected to sustainability.

Pharmaceutical processes are quite complex when compared to other industries. For this reason, the pharmaceutical industries in India and around the world must incorporate sustainability into their overall corporate strategy and report on it to the public for public awareness. This is also among the factors that have made this industry a focus of sustainability efforts over the past 20 years (Esteban 2008). Below is the structure of this chapter. The content of the survey pertains to the specifics of the methodology employed in its compilation.

In this regard, the explanation of the environmental effects of pharmaceutical manufacturing processes adds further clarity. It encapsulates the movement of Indian pharmaceutical producers to embrace sustainability-related practices. An explanation of how the Indian industry has affected the environment opens the book. The main conclusions, key observations, and gaps in the literature are discussed in light of the chapter (Fig. 1).

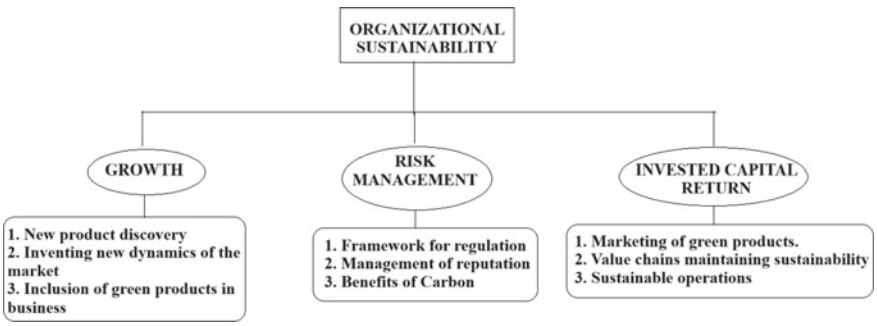

Fig. 1 Balance of sustainability with growth

2 Research Methodology Adopted to Review Research Articles

2.1 Design of Research

Many other documented research forms, such as reports, white papers, and working papers, were examined because the literature on sustainability and related practices in the pharmaceutical sector is not specifically limited to scholarly publications. Keywords from the disciplines of corporate social responsibility, green chemistry, life cycle assessment, sustainable manufacturing, and sustainability in the pharmaceutical business were looked up to gauge the trends. Major findings and potential recommendations have been provided following a review of multiple reports, articles, and online data sources as well as individual papers relating to sustainability in the pharmaceutical business and related areas overall.

In terms of environmental awareness, the years 2010 and 2014 were significant due to their careful consideration of environmental issues and the establishment of new rules and regulations both internationally and in India. It's interesting to note that the majority of scientific research papers, which include various case studies of the pharmaceutical industry, were published in reputable journals such as Business Strategy and The Environment, Green Chemistry, Journal of Cleaner Production, and many more. These journals present cases of process improvement in pharmaceutical manufacturing, including the use of eco-design concepts in early product development, the adoption of less hazardous materials, and alternative manufacturing processes. Together, this reduced waste production, and made sure that energy use and greenhouse gas emissions were reduced, hence reducing the environmental impact and offering financial benefits with improved stakeholder communication.

This chapter is exploratory and is based on a survey of the literature to investigate the practices used by the Indian and global pharmaceutical industries and the enhancements in performance that follow. Using the methods outlined in this chapter, a methodical review of various types of literature was conducted for this goal. Through the study of numerous journal articles, reports, and whitepapers, data in the form of statistical numbers was gathered. Tables were then used to provide a summary.

- Understanding the environmental, economic, and social components of sustainability and its reporting required studying the Global Reporting Initiative guidelines, which are standard.
- Research on the adoption of sustainability-related practices and their reporting has been identified.
- To investigate the knowledge around the adoption of sustainability and its reporting, a thorough assessment of the literature was conducted.
- The pharmaceutical business was selected for additional investigation based on a review of the literature to address qualitative concerns about sustainability relative to practices and their reporting.

- Indian pharmaceutical companies were selected and examined in light of the literature regarding industry practices in the pharmaceutical sector to address sustainability on a global scale.
- Reports were made on observations, important discoveries, gaps, and conclusions about qualitative sustainability challenges to attain sustainability in Indian pharmaceutical companies.

2.2 Trends of Sustainability Growth

Peer-reviewed scientific journal publications have shown that different reporting techniques have occasionally been proposed by various international agencies and governments. The aforementioned initiatives aim to advance, embrace, and include sustainable practices and thought processes. Additionally, they seek to facilitate relevant stakeholder communication across industrial sector organizations globally (Low et al. 2016). The majority of the material on this topic is therefore available as reports and whitepapers, in addition to research articles that are published in scholarly journals. This is a significant discovery. The voluntary guidelines that have been developed are an attempt to address sustainability.

3 Types of Sustainability Analysis

3.1 Social

When it comes to the social component of sustainability, the articles that came out of the review are fewer in number—six in all. This comparative scarcity emphasizes the critical need for further research on this element of sustainability. The analysis of this topic focuses on several concerns, including the function of employees, segments of the population that have access to pharmaceutical compounds, parts linked to supply chains, packaging of the products, and conduct of customers (Caligiuri et al. 2013; Quak et al. 2019; Nematollahi et al. 2018; Lorenzini et al. 2018; Chaar and Lee 2012).

Regarding the contribution of workers and their involvement in social issues, Caligiuri et al. investigate how many employees participate in corporate volunteer initiatives facilitated by NGOs (Caligiuri et al. 2013). In the context of pharmaceuticals, the article examines how these initiatives boost staff involvement, which promotes both the development of CRS policies and employee identification with corporate values. The study report by Quak et al., recommends the use of metrics to assess the capacity of pharmaceutical firms to ensure the public's access to medications. In particular, the authors emphasize prospects for employing the AtM Index, a tool thought to be able to sensitize pharmaceutical corporations towards the issue of

ensuring better access to pharmaceuticals, in their study on drug access in emerging markets (Caligiuri et al. 2013).

To support better access performance, the research emphasizes the necessity to examine sharing arrangements across several stakeholders related to pharmaceuticals. Lorenzini et al. reviewed the significance of pharmaceutical packaging innovation and the role it plays in giving patients more opportunities to get appropriate and effective treatments (Lorenzini et al. 2018). Both the study by Chaar and Lee, which examines consumer behavior about various drug prescription systems, and the study by Sahu and Kohli, which examines the relationship between pharmaceutical companies and hospitals, make clear the necessity of meeting patients' needs by giving them centrality (Chaar and Lee 2012; Sahu and Kohli 2019).

3.2 Environmental Sustainability

The recurrent issue, the environmental aspect of pharmaceutical sustainability is very prominent. Cleaner production, eco-friendly supply chains, eco-friendly human resource management (HRM), and eco-friendly materials are the four main areas of study for the ecological component identified by the thematic study of the full papers. There are research articles addressing ecological challenges that specifically reference production in the pharmaceutical industry as part of the research stream looking at cleaner production, discussing the topic of the ecological impact of products throughout their life cycles and how this is disclosed by businesses (Veleva and Cue 2017). They point out that in the pharmaceutical industry, business transparency does not provide the provision of a holistic picture of this impact. For instance, the paper by Belkhir and Elmeligi, which emphasizes the establishment of a research deficit about this particular sector, emphasizes the necessity to pay attention to how pharmaceutical manufacturing emissions affect the environment (Kaenzig et al. 2011).

Based on an empirical study of several of the top pharmaceutical companies, the authors note that even though their analysis reveals that the pharmaceutical industry's carbon emissions are even higher than those of the automotive industry, which has received much more significant attention, this industry is still largely under the radar and has received little attention. This finding highlights the necessity for policies that give a thorough representation of the sector's carbon footprint. This necessity is also acknowledged in other studies that include both broad articles that analyze more specialized themes as well as papers that strive to understand how to assess efficiency in ecological terms in medicines (Belkhir and Elmeligi 2019). For instance, studies on the significance of ISO certifications and system standards can be found among the latter (Veleva et al. 2003). Li and Hamblin, for instance, underline how ISO14001 certifications are among the most crucial factors in figuring out how pharmaceutical companies use cleaner production practices in their analysis of the Chinese market (Marinkovic et al. 2016). Similar studies have been done in the pharmaceutical industry to attempt and understand the factors that influence entrepreneurs'

attitudes toward carrying out green activities. The supply chain is the topic of the second area of research that we look at that relates to the environmental aspect (Li and Hamblin 2016). According to General Studies, one of the most important factors to think about is the necessity of addressing the environmental issue (Blum-Kusterer and Hussain 2001).

In their study, Singh et al. claim that there is increasing interest in concerns surrounding the management of pharmaceutical product waste and methods to address some of the challenges connected to, for example, the management of expired pharmaceuticals or the risk of pharmaceutical product-related water contamination (Kumar et al. 2019). Undeniably, choosing suppliers and other supply chain participants based on their contribution to ecological effect is a particularly crucial issue in this research (Singh et al. 2016).

For instance, Gardas et al. offer an empirical inquiry to comprehend the selection criteria for third-party logistics service providers in their study of the Indian market. The authors emphasize the role that logistics, in general, and these actors, in particular, play in reducing CO_2 emissions (Moradi and Jolai 2018). They draw attention to a particular research hole in the pharmaceutical industry, offer a framework of 14 criteria, and stress the importance of including other sustainability facets. The significance of a green perspective in HRM that emphasizes green HRM practices is one of the topics on which contemporary writing on pharmaceuticals has concentrated. To establish a zero-waste culture in the company, Veleva et al. emphasize the importance of human resources and the function of employee involvement (Gardas et al. 2019). The adoption of green HRM practices that can encourage pro-environmental behavior by employees is another pertinent subject that Saeed et al. discuss (Veleva et al. 2017). The writers discuss these practices in particular and contrast the pharmaceutical industry with other industries in terms of how they are implemented. According to the findings, it is more probable that sustainable behaviors will be adopted from an environmental standpoint when green HRM practices are integrated into a broader understanding of sustainability in the workplace. In other words, they appear to be associated with a broad strategy for sustainability. Similarly, Masri and Jaaron investigate green HRM practices and their effects on employees' environmental performance in the particular context of Palestinian pharmaceutical firms (Saeed et al. 2019).

Comparison between the pharmaceutical industry with other industries emphasizes the critical importance of personnel selection phases (compared to those of, for example, training) among various HRM practices, emphasizing the need to close a research gap regarding the construction of measurements of the carbon footprint of workers. Instead, Andersson et al. emphasize the importance of managers in motivating employees to behave in a particular way. The development of green materials that the pharmaceutical industry can use for production is the subject of a final line of inquiry (Masri and Jaaron 2017). These more comprehensive studies identify opportunities for the pharmaceutical industry by examining materials and prospective applications. The use of sustainable products like algae, which can be used to make therapeutic agents, or the use of waste from the production of marine resources,

such as fish rather than other food waste, has been suggested in some articles in this field of study (Andersson et al. 2005; Sudhakar et al. 2019; Dave and Routray 2018).

Manda et al. suggest using cutting-edge membranes to remove pharmaceutical waste from water. There is only a small number of research in this area that looks at how environmental and social sustainability interact, as well as how environmental and economic sustainability interact (Mirabella et al. 2014). Azim and Azam examine social and environmental disclosure about the particular instance of Bangladeshi pharmaceutical firms. The authors draw attention to the backlog in the pharmaceutical industry in this area (Manda et al. 2014). The Weraikat et al. research suggests a study to confirm strategies to persuade customers to return unneeded medications.

Advantageous projections are also explored for the environment because drug dispersion is reduced (in line with a vision of environmental sustainability), but it is also advantageous from a social responsibility standpoint because it allows for the possibility of distributing these unused drugs to populations that lack access to them (Azim and Azam 2013). The analyzed studies show an optimization model for the integrated production and distribution planning of a supply chain, with the two (economic and environmental) objectives of cost minimization and greenhouse gas emissions minimization, as well as themes of reverse logistics, which refers to all operations related to the reuse of products and materials, in the supply chain (Weraikat et al. 2016).

3.3 Economical Sustainability

As studied by Aquino et al. the incorporation of an economic logic into management has occurred in many healthcare systems as a result of the need to balance two objectives, namely the need to reduce costs and the need to assure sustainability. On the one hand, this need is frequently seen as a way to minimize costs, leading to a reduction in services rather than increased efficiency, decreased waste, etc. On the other side, with the implementation of protocols and standards in service delivery, the enhancement of efficiency has been translated as the standardization of procedures (Jabbarzadeh et al. 2019).

The study by Aquino et al. explicitly investigates the opportunities provided by technology to reconcile standardization and personalization of healthcare within this context. More particularly, the report emphasizes the need and possibility of pharmaceutical businesses using 3D printing to create customized drugs. Key findings point to a potentially game-changing role for 3D printing in pharmaceutical manufacture and/or compounding as a tool for smarter healthcare (Aquino et al. 2018).

The term ‘economic sustainability’ is also brought up about patent activity. In contrast to their product patents, Azad et al. concentrate on significant pharmaceutical businesses in Bangladesh and their experience in process patent operations. The authors observe that using automation and the purchase of patents alone to achieve sustainability over the long term seems inappropriate. Thus, technical efficiency

is assessed, and it is demonstrated that scale inefficiency is the primary cause of inefficiency in major pharmaceutical enterprises (Aquino et al. 2018).

It has been shown that this kind of inefficiency outperforms pure technical inefficiency. Growth is a proximate indicator of economic viability. The study demonstrates that exports, R&D spending, and prior-year earnings have a beneficial influence on the expansion of SMEs. However, for their long-term growth and survival plan, SMEs in the pharmaceutical business need to focus more on internationalization and value creation through R&D investment.

The financial performance of pharmaceutical firms is also taken into consideration, particularly those that use environmentally friendly manufacturing methods. The managerial issue raised has to do with weighing the costs and advantages of sustainable supply chain management and green manufacturing. In addition to tracking changes in companies' resource and financial performance, Menzel et al. examine annual and sustainability reports made public by businesses. This study concludes that there is no meaningful connection between green manufacturing and financial success; hence, the expected finding that a company's greener manufacturing leads to greater corporate performance is not supported by the results (Azad et al. 2018).

3.4 Comprehensive Approaches

Many papers offer a comprehensive viewpoint by considering all the sustainability factors that affect business sustainability at once (Menzel et al. 2010). Corporate sustainability, which has its roots in sustainability on a global scale, is translated to the business level and is defined as "meeting the needs of a firm's direct and indirect stakeholders (such as shareholders, employees, clients, pressure groups, communities, etc.), without compromising its ability to meet the needs of future stakeholders as well" (Steger et al. 2007). Leonard and Schneider (2004) take a comprehensive approach to sustainability in the pharmaceutical sector, not just considering people and the environment but also profitability. For sustainability activities in all their dimensions—environmental, social, and economic—to be monitored, valued, and controlled like conventional business drivers, they advocate aligning integrated sustainability programs with business goals. In their 2017 article, Chaturvedi et al. address how pharmaceutical corporations balance societal economic and social welfare with environmental sustainability. They suggest a paradigm for organizational sustainability, which may be used interchangeably with the term "corporate sustainability," in which there is a balance between economic growth and financial profits and societal and environmental costs. Vihari et al. (2019) expand organizational sustainability by introducing the concept of organizational learning. Business model innovation—more specifically, innovation in the value proposition, value generation, and value capture system—is also addressed as a significant factor in corporate (Dyllick and Hockerts 2002). Strategic partnerships with non-profit organizations can also improve corporate sustainability and ensure the value of sustainable initiatives (Hansen et al. 2010). Several articles on sustainable supply networks

consider the economic, social, and environmental aspects of this diverse area. Pharmaceutical firms need to concentrate on sustainability issues as institutional pressure to produce more sustainably grows. Additionally, they should extend their responsibility for their activities from production to the entire supply chain with the additional goal of preventing financial losses, environmental and social risks, or scandals (Vihari et al. 2019). The notion that pharmaceutical enterprises must adhere to sustainable supply chain activities, such as sustainable design and development, strategic sourcing, sustainable product returns, and recycling, appears to have widespread support (Walker and Jones 2012). Pharmaceutical businesses must decide how committed they are to sustainable supply chain practices, according to Janatyan et al. (2018). They also suggest using a multi-objective model to construct a pharmaceutical distribution network by the primary sustainability dimensions. The possibility for pharmaceutical businesses to involve their suppliers in their sustainability activities is discussed by Villena and Gioia (2018). Like this, Villena (2019) investigates how sustainability criteria move throughout international supply chains. According to the study, a company's efforts to promote sustainability throughout its supply network are hampered by a lack of collaboration between procurement and internal and external stakeholders. As a result, the buyer's procurement unit must connect with the supplier's procurement unit to flow the buyer's sustainability requirements. Green HRM is linked to green supply chain management and has a beneficial impact on the triple bottom line of sustainability performance, in addition to strategic procurement and supplier engagement (Zahiri et al. 2017). Articles on corporate social responsibility (CSR) frequently incorporate the three sustainability dimensions. The first query relates to how pharmaceutical firms address sustainability concerns in their CSR reports. According to Min et al. (2017), most pharmaceutical companies presently engage in CSR by using the triple-bottom-line strategy of managing their businesses and having a good overall impact. The authors conclude that CSR, regardless of the size of the organization, provides value to corporate financial performance and should be seen as a long-term investment. They contend that pharmaceutical businesses should adopt a CSR strategy because it invests in stakeholder management and fosters partnerships that boost reputation and revenue. According to Schneider et al. (2010), there has been an increase in the breadth and depth of relevant operations across the pharmaceutical industry as they analyze the development of reported sustainability activity. Demir and Min (2019) analyze the consistency and disparities in pharmaceutical companies' CSR reporting. They find that while disclosures on established issues, like the environment and labor relations, exhibit some degree of standardization, those paying particular attention to delicate ones, like human rights and supply chain, are far from being standardized. Performance evaluation of intangibles related to CSR is taken into consideration while talking about it (Zaid et al. 2018). The eight pillars of sustainable operations—people, quality, safety, productivity, availability, environment, community, continuous improvement, and engineering excellence—are evaluated as part of Mistry's (2018) proposal for a performance measuring system.

4 Effect on the Environment Caused by the Pharmaceutical Industry

Human medications are on UNESCO's list of emerging pollutants. According to the "2030 Agenda for Sustainable Development" Goal Targets (Parisi and Hockerts 2011), their detection and removal represent the key stage. Drug levels in the environment are below what is considered therapeutic. Pharmaceuticals are found in amounts lower than 100 ng/L in water surfaces that receive treated wastewater (UNESCO (United Nations Educational, Scientific and Cultural Organization) 2020). Due to these low quantities, it is challenging to determine how harmful these substances are to both human health and the ecology. According to aus der Beek et al. (2016), most medications have not been thoroughly investigated for their potential long-term toxicity, environmental presence, or other impacts. Beta-blockers, antibiotics, anticancer medications, and endocrine disruptors, among other drug classes, have been shown to have devastating effects on the ecosystem, including increased mortality and impairment of the physiological and reproductive processes of aquatic species (Vumazonke et al. 2020; Nie et al. 2013). Furthermore, because it is hard to separate humans from nature, these consequences have a disastrous impact on human health. Due to the enormous number of medications and the difficulties in assessing the dangers associated with multi-compound exposure at low doses and over extended periods, the problem's scope is still largely unclear (Kümmerer 2019). 10% of currently available medications pose a potential environmental risk, according to the German Environment Agency (UBA). Despite the lack of developed detection methods for all pharmaceuticals that enter the ecosystem, some of them are overwhelmingly present and have been shown to have harmful impacts on ecosystems (Küster et al. 2010). Hormones, antibiotics, antidepressants, analgesics, anti-inflammatory drugs, and anticancer medications are some of these categories (Monteiro and Boxall 2010). Estrogens in the environment are a significant source of pollution (Bilal and Igbal 2019). Only the usage of birth control pills is responsible for the about 30,000 kg/yr of naturally occurring steroidal estrogens and an extra 700 kg/yr of manufactured estrogens that are excreted by the world's population. However, the amount of these hormones in the environment is mostly a result of the livestock industry, which uses a range of growth-regulating steroids extensively to boost the rate of meat production. Estrogens are unquestionably necessary for healthy human physiology, but if they build up in the environment and reach the human food chain, they can have major negative effects (Adeel et al. 2017). These hormones can disturb the physiology of both humans and animals and have an impact on regular reproduction (Trevino et al. 2015). Estrogens are also associated with a higher risk of breast cancer in women and prostate cancer in males. Given the increased usage of antibiotics during the COVID-19 pandemic, which resulted in the exhaustion of the final line of antibiotics, antimicrobial resistance is a concern for global public health (Lai et al. 2021). It has been noted that the use of antibiotics in human medicine, veterinary medicine, and agriculture is connected to the contamination of various environmental components,

which led to an increase in antibiotic resistance and the occurrence of ecotoxicological effects (Zainaba et al. 2020). A growing environmental concern to public health is posed by patients' improper antibiotic disposal practices, which include flushing them into sewage systems (Anwar et al. 2020). Additionally, long-term antibiotic pollution exposure can have a negative influence on human health, particularly in people who already have chronic illnesses like obesity, diabetes, or asthma (Ianiro et al. 2016).

During the COVID-19 pandemic, antidepressant contamination considerably increased globally (Rabeea et al. 2021). Antidepressants have been found in both urban and rural water systems up to this point. Diverse antidepressants cause cytotoxicity, genotoxicity, altered stress responses, changes in weight and length, as well as liver and kidney damage, in a variety of aquatic animal species due to bioaccumulation in their tissues (Castillo-Zacarías et al. 2021). Antidepressant pollution (sertraline, fluoxetine) has affected human neurodevelopment and many mental problems since the human and animal habitats largely overlap (Abbey-Lee et al. 2018). Non-steroidal anti-inflammatory drugs, such as acetaminophen, acetylsalicylic acid, ibuprofen, diclofenac, and naproxen, are commonly found in soil, wastewater, surface water, drinking water, and groundwater in high concentrations that significantly contribute to environmental pollution (Tyumina et al. 2020). These medications have long-lasting ecotoxic effects because of how difficult it is for them to be biologically altered by the environment due to their stable chemical structure. By causing oxidative stress and interfering with the action of detoxification enzymes, they are known to predominantly induce diseases in the organs of invertebrates and vertebrates (Hodkovicova et al. 2022). These medications can also impair oocyte maturation via an unidentified mechanism, leading to hepatotoxicity and cardiovascular problems (Lister and Van Der Kraak 2009). These drugs can also impact oocyte maturation, resulting in hepatotoxicity and anomalies in the cardiovascular system, claim Lister and Van Der Kraak (2009) and Xia et al. (2017).

Pharmaceutical substances with the potential to be highly persistent and harmful in the environment include beta-blockers (Küster et al. 2010). While there is a dearth of information regarding their environmental adsorption, it is known that these medications have a somewhat high water solubility and have been found in surface waters at quantities of g/L. These substances are highly hydrolysis-resistant, bioavailable, and transportable in the environment. As a result, their buildup in the environment may have unintended effects on various living things. Metoprolol and propranolol are considered harmful substances to aquatic life by European Union Directive 93/67EEC. This shows the outcomes of tests done on *S. vacuolates*, a type of green alga (Maszkowska et al. 2014).

When anticancer medications are released into the environment, they disrupt fertility and significantly alter the genetic makeup of living things, which has an impact on the ecosystem. Anticancer medications limit the growth and division of cells. Anticancer medications are recommended in smaller doses, but even at ng/L concentrations, they have devastating effects, including harm to aquatic species through mutagenic, carcinogenic, and teratogenic effects. Cytostatic medications are frequently found in hospitals and pharmaceutical manufacturing wastewater because