

Abstract

The pharmaceutical industry, essential for advancing global health, faces significant environmental challenges due to its energy-intensive processes and reliance on hazardous chemicals. This paper explores the integration of environmentally conscious chemistry principles and sustainability benchmarks in the pharmaceutical sector to address these challenges. It highlights the industry's environmental impacts, including high energy consumption, water pollution, waste generation, and plastic pollution. The paper discusses green chemistry as a foundation for reducing these impacts, focusing on principles such as atom economy, safer solvents, and energy efficiency. It also examines key sustainability benchmarks, including carbon neutrality, waste reduction, water stewardship, and greener supply chains. Case studies of leading pharmaceutical companies AstraZeneca, GlaxoSmithKline (GSK), and Pfizer demonstrate practical applications and commitments to sustainability. The paper concludes by emphasizing the need for continued innovation, regulatory support, and collaboration to achieve long-term environmental goals and ensure a sustainable future for the pharmaceutical industry.

Keywords: Green Chemistry; Sustainability Benchmarks; Pharmaceutical Industry; Environmental Impact; Carbon Neutrality; Water Resources

Introduction

The pharmaceutical industry is a critical sector for global health, but it also faces significant environmental challenges. High energy consumption, water pollution, waste generation, and plastic pollution are major concerns. This paper explores the integration of environmentally conscious chemistry principles and sustainability benchmarks in the pharmaceutical sector to address these challenges. It highlights the industry's environmental impacts, including high energy consumption, water pollution, waste generation, and plastic pollution. The paper discusses green chemistry as a foundation for reducing these impacts, focusing on principles such as atom economy, safer solvents, and energy efficiency. It also examines key sustainability benchmarks, including carbon neutrality, waste reduction, water stewardship, and greener supply chains. Case studies of leading pharmaceutical companies AstraZeneca, GlaxoSmithKline (GSK), and Pfizer demonstrate practical applications and commitments to sustainability. The paper concludes by emphasizing the need for continued innovation, regulatory support, and collaboration to achieve long-term environmental goals and ensure a sustainable future for the pharmaceutical industry.

Environmental impact of pharmaceuticals

The pharmaceutical industry is a significant contributor to environmental impacts, including high energy consumption, water pollution, waste generation, and plastic pollution. This paper explores the integration of environmentally conscious chemistry principles and sustainability benchmarks in the pharmaceutical sector to address these challenges. It highlights the industry's environmental impacts, including high energy consumption, water pollution, waste generation, and plastic pollution. The paper discusses green chemistry as a foundation for reducing these impacts, focusing on principles such as atom economy, safer solvents, and energy efficiency. It also examines key sustainability benchmarks, including carbon neutrality, waste reduction, water stewardship, and greener supply chains. Case studies of leading pharmaceutical companies AstraZeneca, GlaxoSmithKline (GSK), and Pfizer demonstrate practical applications and commitments to sustainability. The paper concludes by emphasizing the need for continued innovation, regulatory support, and collaboration to achieve long-term environmental goals and ensure a sustainable future for the pharmaceutical industry.

Energy consumption and emissions:

The pharmaceutical industry is a significant contributor to environmental impacts, including high energy consumption, water pollution, waste generation, and plastic pollution. This paper explores the integration of environmentally conscious chemistry principles and sustainability benchmarks in the pharmaceutical sector to address these challenges. It highlights the industry's environmental impacts, including high energy consumption, water pollution, waste generation, and plastic pollution. The paper discusses green chemistry as a foundation for reducing these impacts, focusing on principles such as atom economy, safer solvents, and energy efficiency. It also examines key sustainability benchmarks, including carbon neutrality, waste reduction, water stewardship, and greener supply chains. Case studies of leading pharmaceutical companies AstraZeneca, GlaxoSmithKline (GSK), and Pfizer demonstrate practical applications and commitments to sustainability. The paper concludes by emphasizing the need for continued innovation, regulatory support, and collaboration to achieve long-term environmental goals and ensure a sustainable future for the pharmaceutical industry.

Energy efficiency: $\frac{E_{CO_2}}{E_{CO_2} + E_{CH_4}}$

Reduction of derivatives: $M_{CO_2} = \frac{E_{CO_2}}{E_{CO_2} + E_{CH_4}}$

Design for degradation: $A_{CO_2} = \frac{E_{CO_2}}{E_{CO_2} + E_{CH_4}}$

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