# Green chemistry is transforming the pharmaceutical industry’s environmental impact



The pharmaceutical industry plays a pivotal role in healthcare but is increasingly recognised as having a considerable environmental footprint. Its operations—from drug development through to manufacturing, distribution, and disposal—contribute significantly to pollution and climate change. Recent studies estimate that the carbon emissions from the pharmaceutical sector may be up to 55% higher than those from the automotive industry. Additionally, pharmaceutical waste, including solvents, reagents, and packaging, enters ecosystems via various pathways such as excretion of unmetabolised drugs, manufacturing plant effluents, agricultural runoff, and domestic wastewater. Active pharmaceutical ingredients (APIs) and their transformation products have been detected in water, soil, and food chains, highlighting the extent of environmental contamination linked to pharmaceutical activities.

In response to these mounting environmental concerns and stricter regulatory landscapes, sustainability initiatives such as green chemistry are gaining prominence within the pharmaceutical sector. Green chemistry, a concept formalised in the 1990s by scientists Paul Anastas and John Warner, is a framework that advocates for the design of safer, more sustainable chemical processes. It aims to achieve environmental benefits while enabling cost savings, regulatory compliance, and improved corporate reputation. The approach is guided by twelve underlying principles, which include waste prevention, maximising atom economy (ensuring that all materials used are efficiently incorporated into the final product), employing safer solvents, and conducting reactions under milder conditions to reduce energy consumption and toxicity.

Key principles of green chemistry relevant to pharmaceuticals also include catalysis, where small amounts of catalysts substitute stoichiometric reagents to reduce waste, and design for degradation, which promotes the creation of chemicals that break down naturally after their intended use, thereby limiting environmental persistence. These tenets challenge traditional synthetic methods that prioritise yield and speed, urging the industry to rethink how pharmaceuticals are synthesised, which solvents are selected, and how reactions are scaled without compromising safety or drug quality.

The increasing importance of green chemistry in pharma is driven by several factors. Regulatory agencies around the world are embedding environmental risk considerations into their frameworks. The European Medicines Agency (EMA), for example, has introduced mandatory environmental risk assessments for new marketing authorisation applications. Moreover, the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation in Europe restricts hazardous chemical use to safeguard human health and the environment. Parallel efforts come from bodies such as the U.S. Environmental Protection Agency (EPA), which promote sustainable manufacturing practices within the sector.

Companies adopting green chemistry often find that it results in more straightforward and efficient synthetic routes. Innovative technologies like continuous flow chemistry and biocatalysis have emerged, helping to reduce energy requirements, solvent waste, and purification steps, ultimately lowering operational costs. Furthermore, Environmental, Social, and Governance (ESG) criteria are becoming increasingly influential in investment decisions, thereby encouraging pharmaceutical firms to prioritise sustainability. Broader green practices such as sustainable sourcing, eco-friendly packaging, and extended producer responsibility schemes are also being explored.

Several leading pharmaceutical companies have already integrated green chemistry into their operations, achieving notable efficiency gains and environmental improvements. For instance, Merck transitioned from batch to continuous manufacturing in producing pembrolizumab (Keytruda®), significantly improving production efficiency while cutting water and energy usage, waste generation, and emissions. Merck’s synthesis of nemtabrutinib was notably streamlined from eleven steps to just two, with toxic solvents replaced by renewable alternatives and catalytic processes introduced to enhance atom economy and safety. Pfizer similarly implemented a greener synthesis of sertraline (Zoloft®), doubling yield, reducing raw material consumption by 20 to 60%, eliminating almost two million pounds of hazardous substances, and substantially lowering energy and water use.

Industry recognition of these innovations is reflected in awards such as the U.S. EPA’s Green Chemistry Challenge Awards and the Peter J. Dunn Award by the American Chemical Society’s Green Chemistry Institute Pharmaceutical Roundtable (GCIPR), which celebrate advances in green chemistry’s industrial and commercial application.

Despite the progress, adoption of green chemistry in the pharmaceutical sector faces challenges. Awareness about pharmaceuticals’ broader environmental impacts remains limited, and environmental data is often underreported, creating knowledge gaps. Calculating carbon footprints poses difficulties owing to variability in geography, production processes, and supply chains. Technical and economic hurdles also exist, as retrofitting existing facilities or redesigning entrenched synthetic routes can involve substantial costs and time.

To address these barriers, new tools and approaches are emerging. Artificial intelligence (AI) and machine learning are being leveraged to optimise reaction pathways with greener outcomes. Resources provided by organisations such as the ACS GCIPR include solvent guides, databases, and sustainability metrics that assist decision-making in the pursuit of greener chemistry.

As the global pharmaceutical industry navigates increasing regulatory pressures and evolving business strategies, green chemistry is set to play a central role in reducing environmental impact while enhancing operational efficiencies. A broad coalition of pharmaceutical professionals, including R&D scientists, engineers, regulatory experts, and sustainability teams, is integral to driving this transformation towards sustainable pharmaceutical development and production.

Source: [Noah Wire Services](https://www.noahwire.com)

## References

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* <https://pmc.ncbi.nlm.nih.gov/articles/PMC10595549/> - Supports claims about pharmaceutical companies' emissions surpassing automotive industry (13% higher) and ESG-focused sustainability efforts.
* <https://www.techtarget.com/pharmalifesciences/feature/Understanding-the-environmental-impact-of-the-pharmaceutical-industry> - Validates pharmaceutical waste generation (300M+ tons plastic/year) and ecosystem contamination risks from APIs and disposal practices.
* <https://eeb.org/the-problem-of-pharmaceutical-pollution/> - Confirms detection of 600+ APIs in the environment, aligning with contamination pathways and environmental persistence claims.
* <https://www.technologynetworks.com/biopharma/articles/the-environmental-impact-of-biotech-and-pharma-operations-380130> - Provides healthcare sector emissions context (4.4% global total), supporting broader environmental impact discussions.