

*Editorial corner – a personal view*

## Safe and sustainable-by-design: Redefining polymer engineering for a greener future

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The field of polymer engineering is at a crossroads where the dual requirements of safety and sustainability are redefining design priorities. Polymers are indispensable to many sectors, including transport, construction, renewable energy, electronics, healthcare and packaging industries. Ensuring that the life-cycle of polymers aligns with environmental and human safety standards is both a challenge and an opportunity. A primary challenge is balancing performance with environmental impact. Polymers often rely on additives that enhance properties but may pose environmental or health risks. For instance, while flame retardants are essential for safety, certain formulations have raised concerns about toxicity (<https://doi.org/10.2823/854233>). Similarly, the recyclability of high-performance polymer blends and composites remains a concern, as their design often hinders efficient end-of-life management (<https://doi.org/10.3144/expresspolymlett.2023.81>). Another challenge is the trade-off between cost and sustainability. Designing polymers from renewable sources or integrating recycled content often increases production costs, restricting their use in cost-sensitive markets. In addition, the current recycling infrastructure is largely incapable of managing advanced materials like thermoset fibre-reinforced composites, leading to landfilling or incineration as default options.

Implementing a circular design approach offers a practical strategy for progress. This involves designing polymers with their end-of-life in mind, enabling reuse, recycling, or biodegradation without

compromising safety. The development of vitrimers, recyclable thermosets featuring dynamic covalent bonds, represents a pioneering example towards achieving a circular economy (<https://doi.org/10.3144/expresspolymlett.2021.89>). Regulatory frameworks can also drive safer and more sustainable design (<https://doi.org/10.2760/28450>) by incentivising greener materials and production processes. The [European Green Deal](#) and initiatives such as [REACH](#) have set ambitious targets, driving the polymer industry to eliminate dangerous substances and move towards environmentally friendly production. Material innovations, such as the replacement of toxic additives or the integration of bio-based feedstocks, are pivotal in addressing health and environmental concerns. Advanced chemical recycling processes, such as solvolysis, hold promise for decomposing complex polymer systems and highly contaminated plastic waste into reusable monomers, enabling closed-loop manufacturing.

Addressing these challenges while ensuring competitiveness requires collaboration across disciplines. Scientists, engineers, and policymakers must unite to establish a shared vision for the future of polymer engineering. Academic research should focus on material innovations and scalable recycling technologies, while industry stakeholders need to invest in eco-design and infrastructure improvements. The path to safe and sustainable-by-design polymers is complex, but with joint effort, it is possible to combine innovation with responsibility.

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