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Editorial: Environmental impacts of materials and their life cycle

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Editorial on the Research Topic
Environmental impacts of materials and their life cycle

Introduction

The rapid pace of industrialization and urbanization has brought significant advancements in infrastructure, energy, and healthcare systems. However, this progress has come at a cost, with material consumption and waste generation reaching unsustainable levels (Lederer et al., 2021). The construction sector alone accounts for substantial carbon emissions, while proliferating plastics has overwhelmed waste management systems worldwide. Sectors such as agriculture and music are grappling with the environmental and ethical challenges of using finite or endangered natural resources.

Life cycle assessment (LCA) has emerged as a critical tool for evaluating these impacts. Understanding a product's environmental impact from start to finish helps us make it more sustainable (Halkos and Aslanidis, 2024). This Research Topic of studies applies LCA methodologies and other innovative approaches to explore the environmental impacts of materials in diverse contexts, highlighting pathways for more sustainable practices (Dervishaj and Gudmundsson, 2024).

Most important findings and recommendations

A significant challenge in the construction sector is the management of waste (Kadaei et al.) generated during building and demolition. One study in this Research Topic focuses on reverse logistics (RL) and identifies 23 challenges to its effective implementation, with "workforce errors and mistakes during execution" having the most weight and impact. Among ten proposed solutions, the most viable include incorporating RL into sustainability programs and fostering strategic collaborations with RL partners. These measures are crucial for reducing the significant waste generated during construction and demolition projects.

Another contribution evaluates the environmental impacts of masonry residential houses using LCA (Fabianova et al.). The study finds that vertical structures contribute the highest environmental burdens, including a calculated share of climate change impacts at 21.59 kg CO_2 eq/m^2/year. Additionally, vertical structures accounted for most of the estimated 15.87 m^3/m^2/year water scarcity impact. These results emphasize the importance of optimizing the material choices and designs in vertical construction to reduce environmental harm.

Wood as a construction material offers a promising alternative to traditional building materials like concrete and steel because of its lower carbon footprint (Delehan et al.). A comparative study assessed the life cycle impacts of wooden houses versus brick houses, revealing that wooden houses have a smaller carbon footprint. Specifically, the global warming potential for the wood-based house during the life cycle stage (A1–A3) was found to be 0.51 kg CO_2 eq/kWh. This study not only underscores wood's environmental benefits but also demonstrates its cost-effectiveness, making it an interesting choice for sustainable construction.

Plastics have become indispensable across industries but pose a significant environmental challenge because of their low recycling rates (Venkatachalam et al.). A study introduces an innovative indicator to quantify the environmental impact of non-recycled plastics, highlighting the gap between recyclability and actual recycling rates. The findings urge stakeholders to prioritize polymers with established recycling pathways, mitigating the significant environmental damage caused by improper plastic waste management.

The healthcare sector generates substantial plastic waste, particularly from single-use products such as surgical instrument packaging. A study explores the potential for recycling polyethylene terephthalate (PET) waste in Australian hospitals (Keul et al.). Results show that transitioning from landfill or incineration to recycling could reduce total climate change impacts by 88%. This reduction underscores the critical role of circular economy practices in managing healthcare plastics and minimizing environmental impacts.

Solar energy is increasingly recognized as a sustainable solution to the global energy crisis (Kannan and Vakeesan, 2016). A study in this Research Topic investigates the optimization of photovoltaic (PV) systems, comparing different configurations to minimize environmental and structural impacts (Rus et al.). The results indicate that east-west-oriented solar panels outperform traditional south-facing configurations in terms of both emission reductions and structural load management (Khatib and Deria, 2022). These findings offer practical guidance for the energy and construction sectors, promoting adopting PV systems that balance environmental and economic considerations.

Innovative reuse of industrial by-products is a critical strategy for reducing waste and promoting sustainability. One study investigates the potential of using mining wastes -coal, marble, and travertine - in agricultural applications (Eker). Results showed that a 50% coal and 50% travertine mixture achieved the maximum plant height increase, while a 25% coal powder and 75% marble mixture yielded the highest number of beans per plant. Notably, all tested mixtures supported plant growth without exceeding permissible heavy metal limits, demonstrating the feasibility of integrating these wastes into agricultural practices.

The music industry faces unique sustainability challenges related to the extraction and use of natural materials for instrument making. One study introduces MusEcology, an interactive decision support tool that visualizes the connections between musical instruments, natural resources, and ecosystems (Kusnick et al.). By enabling users to explore these complex interrelationships, MusEcology fosters interdisciplinary research and informed decision-making, paving the way for sustainable practices in creating musical instruments.

Broader implications and future directions

The studies presented in this Research Topic collectively underscore the importance of adopting life cycle thinking and systemic approaches to sustainability. They show that innovative applications of LCA, reverse logistics, and circular economy principles can mitigate the environmental impacts of material use. For example, integrating RL in construction, optimization of PV configurations, and targeted interventions in plastic recycling highlight actionable pathways for industries to reduce their environmental footprints.

Future research needs to scale these solutions. It must also address challenges like insufficient plastic recycling and inconsistent LCA methodologies. Additionally, policy interventions, such as extended producer responsibility programs, can play a critical role in driving sustainable practices.

Conclusion

The contributions to this Research Topic offer a comprehensive exploration of the environmental impacts of materials across their life cycle. These studies show new ways to manage materials and make them more sustainable. As industries and policymakers grapple with the twin challenges of resource depletion and climate change, the research presented here offers valuable guidance for building a more sustainable future.

Author contributions

AE: Conceptualization, Investigation, Writing–original draft. MP: Conceptualization, Investigation, Writing–review and editing. AL: Writing–review and editing. VV: Writing–review and editing.

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