

Sustainable waste: Tech, circularity, zero-waste.

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Introduction

This article explores how a circular economy approach can transform waste management, specifically focusing on plastic waste in developing nations. It highlights the potential for sustainable growth by shifting from linear 'take-make-dispose' models to systems that prioritize reuse, repair, and recycling. The authors point out challenges like inadequate infrastructure and policy gaps, alongside opportunities for local innovation and community engagement in plastic waste valorization. What this really means is that adopting circular principles can significantly reduce environmental impact and foster economic benefits in these regions, making a strong case for policy support and investment in localized solutions [1].

The paper provides a thorough review of the latest advancements in smart waste management systems, emphasizing the integration of IoT, AI, and big data analytics. It showcases how these technologies are making waste collection more efficient, improving sorting processes, and enhancing overall resource recovery. The discussion touches upon the benefits of real-time monitoring and predictive analytics in optimizing routes and reducing operational costs. Essentially, the article makes clear that smart technologies are pivotal for modernizing waste management infrastructure and driving sustainable urban development [2].

This review analyzes recent life cycle assessment (LCA) studies on different plastic waste management options. It compares environmental impacts of recycling, incineration, landfilling, and chemical conversion methods, providing insight into which strategies offer the most ecological benefits. The authors highlight the complexity of these assessments, given varying material types and regional contexts. Here's the thing: effective plastic waste management needs to consider the full life cycle to truly minimize environmental burdens, moving beyond simple disposal to more resource-efficient pathways [3].

The article delves into the specific challenges and opportunities for sustainable waste management in developing countries. It identifies issues like rapid urbanization, insufficient funding, weak regulatory frameworks, and low public awareness as major hurdles. However, it also points to potential solutions, including informal sector integration, technological adoption, and policy reforms that encour-

age resource recovery. What this means is that localized, context-specific strategies are crucial, often involving a blend of formal and informal approaches, to achieve sustainable waste management in these regions [4].

This review examines the growing role of artificial intelligence (AI) in revolutionizing waste recycling and resource recovery processes. It illustrates how AI-driven systems are improving waste sorting accuracy, optimizing material identification, and predicting waste generation patterns. The authors discuss the application of machine learning in robotics for sorting, image recognition for contamination detection, and predictive modeling for collection logistics. Let's break it down: AI is a game-changer for making recycling more efficient and effective, significantly boosting the recovery of valuable resources and reducing waste sent to landfills [5].

The paper provides an overview of the environmental impacts caused by textile waste and discusses various sustainable management strategies. It highlights issues like water pollution from dyes, microplastic release from synthetic fibers, and landfill burden. The authors then explore solutions such as textile recycling technologies, upcycling, circular fashion models, and consumer awareness campaigns. Here's the thing: managing textile waste effectively requires a multifaceted approach, from innovative recycling to responsible consumption, to mitigate its significant ecological footprint [6].

This review article focuses on recent advances in bioremediation technologies for plastic waste. It examines how microorganisms and enzymes can break down various types of plastics, offering an environmentally friendly alternative to traditional methods. The authors discuss the mechanisms of biodegradation, the types of microbes involved, and the challenges in scaling up these biological processes for widespread application. What this really means is that biological solutions hold significant promise for addressing the global plastic waste crisis, though further research is needed to optimize their efficiency and cost-effectiveness [7].

This paper explores zero-waste strategies for food waste management through a circular economy lens. It emphasizes the importance of preventing food waste at the source, followed by valorization through composting, anaerobic digestion, and other conver-

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Received: 07-Jul-2025, Manuscript No. AEWMR-25-271; Editor assigned: 09-Jul-2025, Pre QC No. AEWMR-25-271 (PQ); Reviewed: 29-Jul-2025, QC No. AEWMR-25-271; Revised: 07-Aug-2025, Manuscript No. AEWMR-25-271 (R); Published: 18-Aug-2025, DOI: 10.35841/aewmr-8.4.271

sion technologies. The authors discuss how these strategies can reduce environmental impacts, recover nutrients, and create economic value. Let's break it down: a true zero-waste approach to food waste requires systemic changes, from policy to consumer behavior, to close the loop and foster more sustainable food systems [8].

The article discusses the challenges and opportunities in managing electronic waste (e-waste) sustainably in Africa. It identifies issues like informal recycling practices, lack of proper infrastructure, and inadequate legislation, which lead to significant environmental and health risks. However, the authors also highlight opportunities for formalizing the sector, implementing extended producer responsibility schemes, and fostering local innovation in recycling technologies. Essentially, addressing e-waste in Africa requires a coordinated effort, balancing economic development with environmental protection through strategic policy and infrastructure investments [9].

This review explores how blockchain technology can enhance transparency and traceability in waste management systems. It details how distributed ledger technology can track waste from generation to final disposal, preventing illegal dumping and improving data integrity for reporting and compliance. The authors discuss the potential for smart contracts to automate processes and incentivize sustainable practices. What this really means is that blockchain offers a powerful tool for building trust and accountability across complex waste supply chains, ultimately supporting more effective and ethical waste management practices [10].

Conclusion

The landscape of waste management is rapidly evolving, driven by efforts to achieve sustainability and efficiency. A central theme is the adoption of circular economy principles, particularly for plastic waste in developing nations, moving beyond linear models to prioritize reuse, repair, and recycling. This shift aims to significantly reduce environmental impact and foster economic benefits through localized innovation and policy support.

Technological advancements are key to modernizing waste infrastructure. Smart waste management systems integrate IoT, Artificial Intelligence (AI), and big data analytics to improve collection, sorting accuracy, and resource recovery, optimizing operations with real-time monitoring and predictive analytics. AI, in particular, is recognized as a game-changer for enhancing recycling efficiency and material identification.

Life Cycle Assessment (LCA) provides crucial insights into the environmental impacts of various waste management options, guiding

decisions towards more resource-efficient pathways. Specific waste streams, such as textile waste, pose unique challenges related to pollution and landfill burden, requiring multifaceted solutions including advanced recycling and circular fashion models. Bioremediation technologies offer an environmentally friendly alternative for plastic waste breakdown using microorganisms, showing promise for scaling up.

Zero-waste strategies, especially for food waste, focus on prevention and valorization through composting and anaerobic digestion to recover nutrients and create economic value, emphasizing systemic changes. Finally, addressing electronic waste (e-waste) challenges in regions like Africa demands formalized sectors and extended producer responsibility. Blockchain technology is also explored for its potential to enhance transparency and traceability in waste supply chains, building trust and accountability across complex systems.

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Citation: Davis MJ. Sustainable waste: Tech, circularity, zero-waste. *Environ Waste Management Recycling*. 2025;08(04):271.