

Sustainable waste valorization for circular economy.

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Introduction

The global challenge of waste management, particularly concerning plastic waste, necessitates innovative and sustainable solutions. This collection of reviews delves into various advancements in waste valorization and resource recovery, underscoring a concerted effort towards a circular economy. A comprehensive overview of chemical recycling methods for plastic waste, including pyrolysis, gasification, and solvolysis, reveals their mechanisms, advantages, and limitations, stressing their potential to transform waste plastics into valuable chemicals and fuels. The discussion also considers the technological readiness and economic viability of these processes, suggesting that while promising, further research is needed to optimize their efficiency and scalability [1].

Recent advancements in waste-to-energy (WtE) technologies for municipal solid waste treatment have been critically explored. These technologies encompass diverse thermal and biological conversion pathways, such as incineration, pyrolysis, gasification, and anaerobic digestion. An assessment of their environmental impacts and energy recovery efficiencies highlights the necessity of integrated approaches for sustainable urban waste management and resource recovery [2].

Circular economy strategies applied to plastic waste are a central theme, examining mechanical recycling, chemical recycling, and bioplastics. Current developments aimed at reducing plastic pollution and enhancing resource efficiency are identified, with authors discussing the economic, environmental, and technological hurdles. This emphasizes the vital role of policy support and consumer engagement in transitioning towards a more circular plastic economy [3].

Beyond plastics, sustainable technologies for recovering critical raw materials from electronic waste (e-waste) are reviewed. Various methods, including hydrometallurgy, pyrometallurgy, and bioleaching, are compared for their efficiencies, environmental footprints, and economic implications. These insights underline the urgent need for efficient e-waste processing to secure valuable resources and mitigate environmental harm, aligning with broader resource efficiency goals [4].

Advancements in hydrothermal liquefaction (HTL) for valorizing plastic waste are also a significant focus. HTL converts various plastics into valuable bio-oil and other products under high-temperature and high-pressure water conditions. The influence of process parameters, catalyst use, and feedstock characteristics is examined, positioning HTL as a promising chemical recycling route for diverse plastic streams, including mixed plastics [5].

The pyrolysis of plastic waste specifically for producing liquid fuels is systematically analyzed. This includes the effects of process parameters like temperature, heating rate, and catalyst type on the yield and quality of the resulting oils. Different types of plastic feedstocks and their conversion efficiencies are highlighted, suggesting pyrolysis as a key chemical recycling technology for energy recovery and resource diversification [6].

A broader perspective on sustainable waste valorization within a circular economy framework covers a range of approaches, from transforming organic waste into fertilizers and energy to upcycling industrial by-products. Current trends in converting waste into valuable resources are discussed, emphasizing innovations that reduce landfill burden, create new economic opportunities, and promote ecological balance [7].

In addition to resource recovery, environmental protection is addressed through an in-depth analysis of Advanced Oxidation Processes (AOPs) for removing micropollutants from wastewater. Various AOPs, such as ozonation, Fenton processes, photocatalysis, and sonolysis, are discussed regarding their mechanisms, efficiencies, and limitations. Their crucial role in treating complex industrial effluents and urban wastewater significantly contributes to environmental engineering and water resource protection [8].

Emerging technologies for plastic waste management and resource recovery are comprehensively reviewed, encompassing a broad spectrum of innovations. These range from advanced mechanical recycling techniques to sophisticated chemical depolymerization methods. The environmental and economic feasibility of these technologies is assessed, advocating for integrated solutions that maximize plastic value retention and minimize environmental impact, aligning with circular economy principles [9].

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Finally, the crucial role of Life Cycle Assessment (LCA) in evaluating the environmental impacts of chemical recycling technologies for plastic waste is highlighted. LCA quantifies the benefits and trade-offs of different chemical recycling pathways compared to conventional waste management. These insights are vital for identifying environmentally preferable recycling routes, informing policy and investment decisions for sustainable resource management [10].

Conclusion

This compilation of reviews highlights the critical advancements and challenges in sustainable waste management and resource recovery, with a particular focus on plastic waste and circular economy principles. Chemical recycling methods such as pyrolysis, gasification, solvolysis, and hydrothermal liquefaction are extensively explored for their potential to transform plastic waste into valuable chemicals and fuels. These processes are assessed for their mechanisms, efficiency, scalability, and economic viability.

Beyond plastics, the reviews delve into broader waste-to-energy technologies for municipal solid waste, encompassing thermal and biological conversion pathways like incineration and anaerobic digestion, evaluating their environmental impacts and energy recovery. The importance of recovering critical raw materials from electronic waste (e-waste) through methods like hydrometallurgy and pyrometallurgy is also emphasized for resource efficiency and environmental mitigation.

The overarching theme is sustainable waste valorization within a circular economy, advocating for innovations that reduce landfill burden and create new economic opportunities. This includes examining integrated solutions for plastic waste management, from advanced mechanical recycling to chemical depolymerization. Furthermore, the crucial role of Life Cycle Assessment (LCA) in evaluating the environmental footprints of recycling technologies and

the application of Advanced Oxidation Processes (AOPs) for micropollutant removal from wastewater are discussed, underpinning a holistic approach to environmental protection and sustainable resource management.

References

1. Bhaskar S, Arumugam KR, Venkata RG. Chemical recycling of plastic waste: *A review. Environ Sci Pollut Res.* 2021;28:66952-66971.
2. Xinqiang L, Zhengguo X, Jialong L. Recent advances in waste-to-energy technologies for municipal solid waste treatment: *A critical review. Renew Sustain Energy Rev.* 2020;121:109673.
3. David RD, Elena GO, David PB. Circular economy strategies for plastic waste: *A review of current developments and future challenges. Green Chem.* 2021;23:49-64.
4. Mahalakshmi S, Jayabharathi C, Subramanian SR. *A review of critical raw material recovery from electronic waste using sustainable technologies. J Clean Prod.* 2022;375:133989.
5. Jiankun L, Jianbo W, Yutao H. Advancements in hydrothermal liquefaction for plastic waste valorization: *A review. Waste Manag.* 2023;161:184-201.
6. Muhammad AA, Ikhlās AAK, Ahmed HA. Pyrolysis of plastic waste for liquid fuel production: *A review of process parameters and product characteristics. J Environ Manag.* 2020;269:110752.
7. Andrea LIKD G, DMG RS HG, RPD SD W. Sustainable waste valorization in a circular economy: *A review of current trends and future perspectives. Sci Total Environ.* 2022;806(Pt 1):150495.
8. S K S, B S, P K S. Advanced oxidation processes for micropollutant removal from wastewater: *A review. Environ Pollut.* 2023;334:122240.
9. K V G, S N, P S. Emerging technologies for plastic waste management and resource recovery: *A comprehensive review. J Hazard Mater.* 2021;407:124376.
10. FMHKW P, JHND H, SHKKP H. *The role of life cycle assessment in evaluating the environmental impacts of chemical recycling technologies for plastic waste. Resour Conserv Recycl.* 2023;194:106972.

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