Turning Cigarette Butts into Treasure: A Circular Fix

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ABSTRACT

Cigarette butts (CBs) are the most littered waste item globally, with trillions discarded annually, leading to persistent environmental pollution due to their non-biodegradable cellulose acetate filters and toxic contents. This review explores practical remediation technologies that convert CB waste into valuable resources through material integration, cellulose recovery, biorefinery processes, and supportive policy mechanisms. These approaches significantly reduce environmental impacts while promoting resource efficiency. Key findings highlight the feasibility of incorporating CBs into construction materials, recovering cellulose acetate for water treatment membranes, and applying thermochemical conversions. Combined with collection strategies like deposit-refund systems, these technologies offer a comprehensive pathway toward mitigating CB pollution.

INTRODUCTION

Cigarette butts (CBs) represent one of the most widespread forms of anthropogenic litter, with approximately 4.5 to 5 trillion units discarded worldwide each year (Battista, 2025; Stri *et al.*, 2025). Composed mainly of cellulose acetate—a plastic that degrades very slowly—along with residual tobacco, heavy metals, nicotine, and other toxic chemicals, CBs contaminate soil, waterways, and marine ecosystems. They leach harmful substances that affect aquatic life, plant growth, and potentially human health through the food chain (Faisal *et al*., 2024; Shah *et al*., 2023).

Conventional disposal methods like landfilling and incineration are inadequate, as they can lead to further toxin release or greenhouse gas emissions. In response, researchers have developed innovative remediation technologies focused on waste valorization. These methods not only clean up the environment but also create useful products, aligning with circular economy principles. This article provides an accessible overview of these technologies for readers across disciplines, emphasizing practical applications and their environmental benefits (Pazzaglia *et al*., 2025; Rahman *et al*., 2020).

Integration into Construction Materials

One of the most straightforward remediation strategies involves incorporating shredded CBs into building and infrastructure materials.

Pazzaglia *et al*. (2025) demonstrated through life cycle assessment (LCA) that adding 2.5% CBs by weight to gypsum panels as a partial substitute for mineral fillers reduces several environmental impact categories due to resource savings and waste diversion. Panels with up to 50% CBs showed comparable performance to commercial insulation materials in terms of thermal resistance and overall sustainability. The process improves thermal insulation and acoustic properties, making the panels suitable for sustainable construction.

In road construction, Rahman *et al*. (2020) found that pre-processed CBs (0.2–0.5% by weight) act as effective fiber modifiers in bitumen for asphalt concrete. These modified binders exhibited improved physical and rheological properties, such as better penetration, softening point, and viscosity, often outperforming traditional cellulose fibers. This approach diverts waste while enhancing pavement performance with minimal leaching risks.

Additionally, incorporating CBs into fired clay bricks (up to 5–10%) reduces density and thermal conductivity, beneficial for insulation, while maintaining acceptable mechanical strength (Shah *et al*., 2023).

Table 1: Summary of CB Incorporation in Construction Materials

Material	CB Content	Key Improvements	Reference
Gypsum Panels	2.5–50%	Enhanced insulation, lower impacts	Pazzaglia *et al.* (2025)
Asphalt Concrete	0.2–0.5%	Better binder properties	Rahman *et al.* (2020)
Clay Bricks	5–10%	Reduced thermal conductivity	Shah *et al.* (2023)

These applications are scalable using existing industrial processes and offer immediate pollution reduction.

Recovery of Cellulose Acetate and Membrane Fabrication

CB filters contain high-quality cellulose acetate (CA) that can be recovered through eco-friendly methods. Friuli *et al*. (2025) developed a green solvent-based protocol using acetic acid for solubilization and desolubilization under mild conditions. These yields recycled CA (RCA) with properties comparable to virgin material, avoiding toxic solvents common in other processes.

The recovered CA is then used to fabricate membranes for water remediation. In one application, phase-inverted CA membranes incorporated with silver/copper oxide nanoparticles achieved high pure water flux (up to 73 $L/m^2/h$) and 92% salt rejection in reverse osmosis tests, along with good anti-fouling properties (Mafhala *et al*., 2026). These membranes also demonstrate potential for dye removal, such as methylene blue (up to

92% efficiency with modifications). Such technologies provide low-cost, decentralized solutions for water treatment in water-scarce regions.

Biorefinery and Thermochemical Conversion

Advanced biorefinery approaches further expand CB valorization. Battista (2025) reviewed processes like deacetylation to enhance CA accessibility for enzymatic hydrolysis into fermentable sugars, enabling bioethanol production. Thermochemical methods, particularly pyrolysis, convert CBs into biofuels, activated carbon, and other valuable products like carbon black (Hazbehiean *et al.*, 2022).

These routes address toxicity concerns while generating energy and materials, though challenges in scalability and process optimization remain. Hybrid approaches combining CBs with other wastes show promise for higher yields.

Policy Support for Effective Remediation

Technological solutions require efficient collection systems. Stri *et al*. (2025) evaluated deposit-refund systems (DRS) in Japan and Indonesia, finding strong public support (63–91%), especially when paired with environmental education. Producer-managed DRS models align with extended producer responsibility principles, incentivizing proper disposal and funding recycling efforts.

CONCLUSION

Remediation technologies for cigarette butt pollution offer practical, impactful solutions that transform hazardous waste into resources for construction, water treatment, and energy production (Pazzaglia *et al*., 2025; Friuli *et al*., 2025; Battista, 2025). By integrating CBs into gypsum panels, asphalt, membranes, and biorefinery outputs, significant environmental burdens can be alleviated. Supporting policies like deposit-refund systems are essential for collection and scalability. Future efforts should focus on large-scale implementation, public awareness, and further optimization to fully realize a circular economy for CB waste. Widespread adoption of these approaches can lead to cleaner environments and more sustainable material cycles.

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