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REVIEW ARTICLE

# Adult Diaper Waste in Landfills: A Critical Review of Systemic Failure and Pragmatic Pathways

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## Abstract

The increasing use of adult incontinence products, driven by global demographic aging, constitutes a major under-addressed waste stream**.** Our objective was to address this growing problem through a dedicated critical review focused specifically on adult incontinence product waste. A systematic search (PubMed, Science Direct, Google Scholar; 2020–2025) following a modified PRISMA framework identified 20 studies for thematic synthesis. We outline the persistent synthetic composition of adult diapers and their predominant landfill disposal due to regulatory and infrastructure deficiencies. Critical evaluation of LCA and recycling studies revealed that no recycling process has yet reached technological maturity. Based on our evaluation, we propose a pragmatic framework encompassing: (1) policy intervention to mandate landfill diversion; (2) public education to promote separate disposal; and (3) investment in scalable thermal treatment technologies such as Waste-to-Energy incineration with Carbon Capture Utilization and Storage and pyrolysis. Robust Extended Producer Responsibility schemes, coupled with innovative global funding mechanisms, are necessary to enable sustainable AHP waste management in developing countries.

**Keywords** Adult Diaper · Absorbent Hygiene Products (AHPs) · Incontinence Products · Waste-to-Energy (WtE) · Pyrolysis · Extended Producer Responsibility (EPR) · Landfill

## 1. Introduction

The impetus for this critical review emerged from a discussion with a researcher analysing excavated aged landfill waste, who noted that soiled adult diapers remained visibly intact after a decade, while feminine pads and baby diapers had significantly disintegrated. This observation aligns with scholarly assessments highlighting the extreme resistance of disposable absorbent hygiene products (AHPs) to degradation in landfill environments (Cano et al., 2025). Yet despite the globally widespread usage of adult diapers, a subsequent literature search using keywords such as "adult diapers aged landfill waste" yielded no dedicated publications on this issue. This gap between the observable environmental persistence of adult diaper waste and the lack of focused research motivated the present critical review.

The demand for adult diapers is substantial and growing. An estimated 200 million people worldwide experience urinary incontinence, half of whom are over 60 and often manage comorbid health conditions (Diadiun et al., 2021). Currently, approximately 15 billion units are produced annually. The adult diaper market

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exceeded USD 18 billion in 2024, with projections indicating 60% growth within the next decade (Market Growth Reports, 2023).

The term "Absorbent Hygiene Products" (AHP) encompasses sanitary pads, baby diapers, and adult diapers. Consumer purchasing decisions typically prioritize price, absorbency, and discretion. Product packaging highlights quantity and absorbency while material composition is listed in small print. Crucially, packaging lacks warnings about non-biodegradability or instructions for separate disposal from household waste. This omission reflects a systemic regulatory failure to govern AHP production, marketing, and waste management.

While recent reviews have addressed sustainability issues in baby diaper disposal (Iskandar Shah et al., 2025) and healthcare plastic waste (Cano et al., 2025), no dedicated critical review has focused specifically on the unique challenges of adult diaper waste. This waste stream is complex and logistically challenging due to the mixture of synthetic materials and faecal waste. This review addresses this gap by providing a critical analysis of adult diaper waste management, with an emphasis on evaluating the feasibility of current regulatory and technological practices to identify practical solutions for sustainable waste management. It aims to: (i) critically analyse the systemic failures in current adult diaper waste management, including regulatory gaps, consumer misconceptions, and technological limitations; (ii) evaluate the feasibility of commonly proposed solutions such as recycling and biodegradability; and (iii) propose a pragmatic, actionable framework for sustainable management that considers diverse national contexts.

This review is positioned at the intersection of circular economy theory and waste management practice. While circular economy discourse emphasizes waste prevention, reuse, and recycling, our analysis reveals that these principles encounter significant implementation barriers for adult diaper waste. Unlike baby diapers that are typically used for under three years, especially amid declining birth rates, adult diapers may be needed for decades, amplifying the growth of this waste stream (Brewster et al., 2022). Reuse, one of the core circular economy principles, is particularly challenging in this context. The biological nature of the waste and associated infection risks render reusable or washable adult diapers impractical for most settings, and they are therefore not considered further in this review.

Although adult and baby diapers share core materials: a polyethylene outer layer, SAP core often mixed with wood pulp or synthetic fluff, and synthetic adhesives (Holdway & Dowling, 2023), their designs and material volumes differ to address physiological needs. The adult diaper's composition is inherently non-biodegradable, engineered for durability and high absorbency rather than environmental degradation. Its surface layers consist of robust polymers, polypropylene (PP) and polyethylene (PE), constituting approximately 20% of the mass. The core absorbent layer is SAP (about 60%), often mixed with cellulose fluff derived from intensively processed wood pulp. A top layer of PP provides a comfortable, non-woven surface that allows liquid passage, while underlying polyester facilitates fluid transfer. Leakage is prevented by PE films and polymer-based adhesive tapes (Booker & Rippon, 2020). While exact proportions vary, adult diaper composition is essentially petroleum-derived materials with a minor fraction of highly processed cellulose.

It is possible that a majority of consumers of baby diapers, feminine pads, and adult diapers mistakenly assume that all AHPs are made of the same materials and are safe for landfill disposal. This misperception may stem from the product's hygiene function, leading many consumers to assume that diapers are biodegradable. Meanwhile, manufacturers of AHPs do not highlight the non-biodegradable composition of their products, nor do they clarify that the presence of biowaste does not induce biodegradation. An apt analogy is plastic food packaging: once the food is consumed, the plastic container remains part of the plastic waste stream. Notably, adult diapers do not belong to the standard plastic waste or healthcare plastic waste (HCP) categories (Cano et al., 2025), even though healthcare facilities regularly dispose of large volumes of AHP waste. The EPA report (2022) categorizes soiled diapers under "other" waste within household municipal solid waste. This classification implicitly suggests unknown composition and insignificant contribution to the total waste stream, even though the composition of diapers and the nature of the biowaste they contain are well-documented. This classification reflects a regulatory gap rather than an accurate representation of the waste stream. Furthermore, the lack of consumer awareness, compounded by the absence of appropriate solid waste management systems, frequently results in improper disposal of AHP waste in public toilets, open dumps, and waterways, thereby exacerbating public health risks and odor nuisance.

Consequently, current AHP waste management perpetuates an inherent linear economy: petroleum extraction → diaper production → use → landfill disposal, undermining prospects for achieving SDG 12 (Responsible Consumption and Production), while the persistent associated environmental pollution diminishes attainment of SDG 3 (Good Health and Well-being) and SDG 11 (Sustainable Cities and Communities).

The remainder of this review is organized as follows. Section 2 describes the methodology, including the search strategy, selection criteria, and thematic synthesis approach. Section 3 examines regulatory and solid waste management challenges. Section 4 analyses consumer behaviour and awareness. Section 5 critically evaluates LCA findings and associated uncertainties. Section 6 discusses AHP recycling and material recovery barriers. Section 7 proposes a framework for AHP waste management. Section 8 concludes the review by acknowledging limitations and presenting recommendations.

## 2. Methodology

This review employed a systematic, yet deliberately scoped, literature search methodology to construct a critical analysis of adult diaper waste management. The approach was guided by a modified PRISMA framework (Page et al., 2021), adapted to the specific needs of a critical review, rather than a full systematic review with meta-analysis. Figure 1 presents the adopted PRISMA framework diagram. The definitive search was conducted in December, 2025, and focused on publications from January 2020 to December 2025 to capture the contemporary technological and regulatory landscape. Searches were executed in three primary databases: PubMed, Science Direct, and Google Scholar, using a core set of keyword combinations. In PubMed, the query ` ("adult diaper*" OR "adult incontinence product*" OR "absorbent hygiene product*") AND (treatment OR disposal OR "waste management" OR recycling)` yielded 7 articles. In Science Direct, a focused search for `("adult diapers") AND ("waste management") AND ("circular economy")` returned 1,381 results. Additional records were identified through targeted searches in key journals including "Waste Management" and "Resources, Conservation and Recycling", yielding 17 articles. A parallel search in Google Scholar using `("adult diaper" AND "waste management")` scanned for grey literature, with the first two pages of results examined to capture relevant conference papers and technical reports, yielding 450 records. Subsequently, the identified records were subjected to screening. Studies were included if they directly addressed the composition, treatment technology, environmental impact, consumer behavior, or policy related to *adult* incontinence products. Studies focusing only on baby diapers or feminine hygiene products without comparative adult diaper data were excluded. Literature focusing only on material science for manufacturing

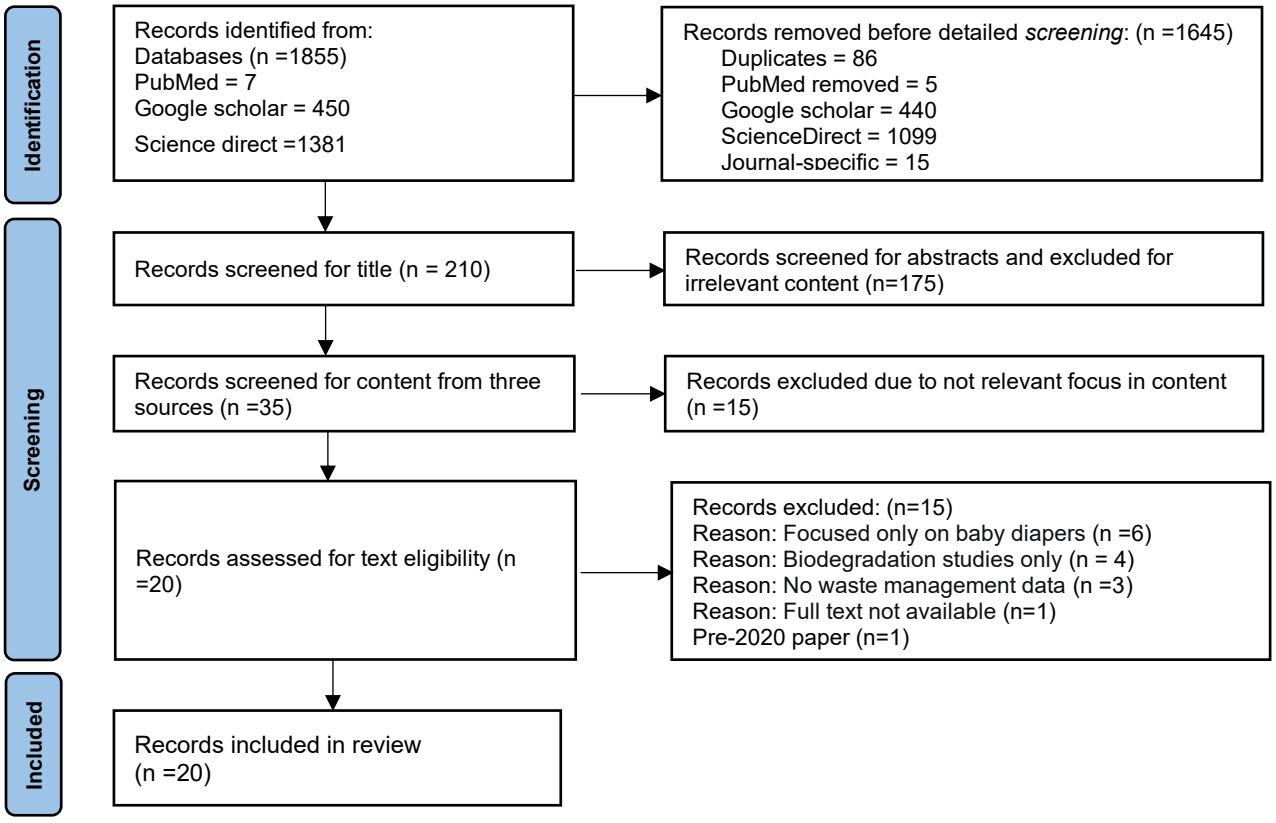


**Figure 1.** Flowchart of adopted PRISMA framework for selection of journal papers.

without a clear waste management perspective was also omitted. This scope definition follows standard critical review practice, where boundaries are set to maintain analytical coherence. At the screening stage, 1,855 records were examined. After removing duplicates (n = 86) and records deemed irrelevant based on subject area, publication date (2020–2025), document type, and title relevance (n = 1,559), 210 records were selected for abstract and content screening. Upon closer screening, 175 records were excluded and 35 full text articles selected for detailed assessment. Out of 35, 15 records were excluded for the following reasons: exclusive focus on baby diapers (n = 6); biodegradation evaluation studies of mixed wastes (n = 4); lack of waste management data (n = 3); full text not available (n = 1); and pre-2020 publication (n = 1). Finally, 20 full length papers in English language were included in this critical review. The selected studies were analysed applying thematic synthesis approach. All sources were evaluated from the perspectives of dedicated originality, methodological rigor, and contribution to developing a pragmatic and sustainable waste management model. This process yielded five dominant themes:

- Regulatory and solid waste management deficiencies
- Consumer behaviour and awareness
- LCA uncertainties and methodological limitations
- Recycling and material recovery barriers
- Pragmatic technological pathways

We acknowledge that the exclusion of non-English articles and the focus on peer-reviewed literature may introduce language and publication bias. The relatively small number of included studies (n = 20) reflects the under-researched nature of adult incontinence product waste specifically, rather than a limitation of the search strategy.

## 3. Regulatory and Solid Waste Management Issues

Landfill practice has faced challenges in numerous countries due to volume overload, complex waste mixing, and the disposal of hazardous materials that can compromise liner integrity and anaerobic process efficiency, potentially leading to long-term soil and water contamination. Consequently, landfill disposal may not be a viable endpoint for adult diapers or other synthetic polymers. A shift toward sustainability would involve phasing out landfill practices. Despite this, global solid waste management regulations lack specific handling and disposal requirements for AHPs waste from household sources. While plastic pollution is now a recognized global crisis, international coordination on plastic waste management remains slow. A global initiative by the United Nations to forge a binding plastic pollution treaty (UN Environment Assembly, 2022; UN Environment Programme, 2024) faces significant hurdles, primarily due to the "cradle-to-grave" commitment requiring nations to assume responsibility for the entire plastic lifecycle locally. One perspective is that this treaty could be expansive to cover waste of synthetic nature more broadly in view of the stronger impact of the international environmental laws on communities at all levels. Historical precedent suggests that stringent, well-enforced regulations tend to be more effective than lenient policies. The Love Canal disaster of the 1970s, for instance, spurred the creation of the U.S. Superfund law (CERCLA), which set a global benchmark for hazardous waste management (U.S. EPA, 2020). In a similar manner, a framework for sustainable AHP waste management could encompass four interdependent pillars: regulatory enforcement, technological advancement, public participation, and infrastructure development (Iskandar Shah et al., 2025). These elements are foundational for addressing large-scale solid waste management issues.

Regulatory tools like Extended Producer Responsibility (EPR), enacted in South Korea, Canada, and France as early as 2003, have increased plastic recycling rates, though overall plastic waste volume has continued to grow (Kwon et al., 2023). Within the European Union, the Landfill Directive (1999/31/EC) has led member countries such as the Netherlands, Austria, Denmark, and Sweden to implement high landfill taxes and, in some cases, bans on the disposal of combustible waste to landfill. These regulatory and fiscal instruments have helped divert substantial waste streams, including plastics and AHPs wastes, from landfills to recycling and Waste-to-Energy (WtE) facilities equipped with post-combustion control technologies.

In contrast, the situation in developing nations has proven more challenging due to continued reliance on landfill disposal. While solid waste management regulations exist in many places, enforcement gaps often result in poor waste segregation at the source, meaning AHP waste commonly ends up in landfills. Even in

Australia, adult diaper waste already exceeds baby diaper waste by a factor of four and is projected to grow tenfold by 2030. This trend observed globally and driven by demographic aging and healthcare sector advances (Brewster et al., 2022). The specific design and consumption patterns of adult diapers suggest a need for dedicated policy attention. New regulatory provisions could help divert AHP waste from landfills to energy recovery. A pilot initiative in Spain involving source-separation of AHP waste found that adult diapers constituted 46–63% of the separated stream, all of which is currently landfilled (Gallardo et al., 2025). The authors advocate for mandatory source-separation to enable direct treatment of this waste category. Effective solid waste management regulations are important for implementing such source-segregation at households and care centers, streamlining logistics for WtE incineration.

Currently, only the United Kingdom mandates that AHP waste from healthcare and social care providers be placed in designated "offensive/hygiene" bags for incineration. However, AHP waste from households can still end up in landfill due to the absence of a national landfill ban. Germany, Sweden, and Switzerland have implemented such bans and primarily treat municipal solid waste at WtE plants producing electricity (Bus et al., 2025). Suitable locations for waste treatment infrastructure and accurate estimations of waste volumes are important for planning collection networks and treatment facilities (Brewster et al., 2024). In smaller communities, innovative designs such as electricity-powered bins that shred used diapers for composting (Kashyap et al., 2021) can support source-separation efforts. Comparing the two major routes of AHP waste disposal, landfill and incineration, the latter has certain advantages from a practical standpoint as it destroys waste and can generate energy. A key consideration is carbon dioxide emissions, which can be addressed through advances in Carbon Capture, Utilization, and Storage (CCUS) technologies, such as amine-based $CO_2$ absorption. Landfill offers fewer comparable advantages and may perpetuate long-term environmental liabilities, particularly where landfill management is inadequate. While anaerobic digestion can be effective at small-to-medium scales for organic waste treatment in rural settings, it has proven less suitable for large-scale, heterogeneous waste streams. Furthermore, enforced Extended Producer Responsibility (EPR) schemes for AHPs could address several interrelated gaps: they would require manufacturers to take responsibility for end-of-life treatment, fund collection infrastructure, and ensure accurate product labelling including clarifying that diapers remain non-biodegradable regardless of their content. Such measures are consistent with SDG 12 (Responsible Consumption and Production) and would help correct misconceptions that currently undermine sustainable waste management. Overall, application of the waste management hierarchy (prevention, reuse, recycling, recovery, disposal) to AHP waste suggests several considerations:

- **Prevention and Reuse:** Reduced production and reusable diaper use are limited by consumer preferences for hygiene and convenience.
- **Recycling:** Separating components can be resource-intensive, and recovered materials often do not match virgin polymer quality. Without sufficient market demand, recycling faces economic challenges.
- **Recovery:** Presently energy recovery via WtE incineration represents a pragmatic option for diverting AHPs waste from landfill.

## 4. Consumer Behaviour and Awareness

Consumer preference tends to favour disposable diapers, often driven by concerns over personal hygiene and convenience (Indrawati et al., 2024). While reusable fabric diapers offer an alternative, their adoption faces practical barriers as they require time and resources for laundering. Furthermore, they are associated with infection risks making reusability as impractical solution. While disposable adult diapers have become widely accessible across diverse consumer groups. Adult diaper use is primarily associated with elderly individuals and those with limited mobility. In geriatric care, their use is frequently influenced by caregiver convenience. Historically, these products were designed first for medical incontinence, second for bedridden patients, and subsequently for general elderly convenience (Bus et al., 2025). With approximately one-third of the global population now over 60 years of age, the scale of this user group is projected to increase steadily. The marketing of so-called "biodegradable" diapers often involves partial replacement of superabsorbent polymer (SAP) with processed plant cellulose, which can compromise absorbency (Denagbe et al., 2025). This trade-off may limit consumer acceptance, reflecting patterns observed in other markets where product performance and cost tend to outweigh perceived environmental benefits (Indrawati et al., 2024). Addressing these challenges requires a

deeper understanding of how consumers perceive AH products and their disposal. The presence of significant organic waste in used diapers may lead consumers to mistakenly assume the product is biodegradable (Brewster et al. 2022). This misconception is compounded by marketing practices that emphasize bio-based content without clarifying end-of-life outcomes. Moreover, focusing sustainability efforts solely on individual consumer choice is also inadequate (Vaittinen et al., 2024). Instead a wider socio-technical ecosystems where sustainable infrastructures, technologies, and care practices support one another are needed. This suggests that consumer awareness campaigns, while important, are most effective when accompanied by clear product labeling, accessible disposal infrastructure, and accountability mechanisms that extend beyond the individual consumer.

The challenges of AHP waste management are particularly acute in developing countries. In South Africa, for instance, where municipal waste collection systems are often absent, AHP waste is commonly discarded in open areas and water bodies. This practice contributes to environmental pollution and has been associated with mental health distress in communities where daily survival concerns take precedence over waste management (Slekiene et al., 2024). Addressing these complex situations requires coordinated international support and the implementation of practical, context-specific solutions at the local level, where large-scale capacity-building programs may be less effective.

## 5. Life Cycle Assessment Uncertainties

Life Cycle Assessment (LCA) offers a valuable framework for comparing the environmental impacts of different waste management pathways. Studies in this field consistently highlight the trade-offs between options such as landfilling, incineration, and recycling (Gu et al., 2023; Iskandar Shah et al., 2025). For adult diaper waste, LCA findings generally indicate that incineration carries a higher carbon footprint than theoretical recycling endpoints, while landfilling raises concerns about long-term environmental persistence and pathogen accumulation (Somers et al., 2021). These insights are methodologically sound under the assumptions made, and they serve an important role in identifying where environmental burdens are concentrated. At the same time, a closer look at the literature reveals that LCA outcomes are highly sensitive to the assumptions embedded in each study. For instance, Gu et al. (2023) examined the environmental impact of adult incontinence products in China and noted that many LCA studies focus narrowly on energy savings and carbon emissions without fully accounting for the logistical and infrastructural realities of waste management in different national contexts. Similarly, Iskandar Shah et al. (2025), in a systematic review of disposable baby diaper waste, observed that LCA comparisons often assume functioning recycling infrastructure and high rates of consumer compliance, conditions that are not common for adult diaper waste stream.

Another consideration is where LCA studies draw their system boundaries. Many begin at the point waste enters a treatment facility, which tends to minimize the logistical and behavioural challenges of collection and source-separation. However, in many developing countries economy contexts, where the waste crisis is most acute, municipal collection is inconsistent and households receive little guidance on proper disposal (Slekiene et al., 2024). By abstracting away these upstream barriers, LCA models may overestimate the feasibility of recycling-based solutions and underestimate the practical challenges of implementation. When it comes to thermal treatment, the picture is more nuanced than a simple comparison between incineration and landfill. Incineration with energy recovery has proven effective in diverting waste from landfills, as demonstrated by operational Waste-to-Energy (WtE) facilities across the European Union. Its primary drawback is carbon dioxide emissions that can be addressed through the integration of sufficiently mature and flexible Carbon Capture, Utilization, and Storage (CCUS) technologies. Pilot-scale projects, such as the amine-based capture system at the Fortum Oslo Varme WtE plant demonstrated capturing over 90% of $CO_2$ emissions (Fagerlund et al., 2021). Moreover, thermal treatment technologies are not limited to large-scale installations. Incineration, pyrolysis and gasification technologies offer flexible alternatives that can be deployed at smaller scales, making them potentially suitable for decentralized applications in smaller municipalities or developing regions (Kwon et al., 2023).

LCA findings can be viewed as valuable inputs to a broader conversation on identification of trade-offs and specific assumptions that influence outcomes most. The technological approaches can be considered in various combinations to select most feasible and sustainable in a context of local infrastructure, economic capacity,

and waste characteristics. By acknowledging the limitations of existing LCA studies such as the ideal assumptions about recycling infrastructure and the exclusion of CCUS from most incineration scenarios, it is probable to use them more constructively for pragmatic developments within localized context. The following sections therefore focus on the tangible barriers to recycling and biodegradability, and on the conditions under which thermal treatment with carbon management may offer a viable solution.

## 6. Recycling and Material Recovery Barriers

This brief historical trajectory helps explain why the adult diaper manufacturing is now locked into synthetic materials. The first baby diaper was patented in the United States in 1951. Initial designs using paper proved economically unfeasible, leading to the use of processed sawdust, which made diapers bulkier and heavier. In the 1950s, newly developed synthetic superabsorbent polymers (SAP) revolutionized the industry and extended the market to adult diapers (Diadiun et al., 2021). This dependency on synthetic materials for performance and cost has made a return to natural absorbents technically and economically challenging. The recycling of adult diapers faces significant economic and technical challenges that have limited its scalability to date. Initial attempts focused on soiled baby diapers in the European Union demonstrated the complexity of a process that required integrated mechanical separation, chemical sterilization, and thermal treatment within a well-developed infrastructure (Iskandar Shah et al., 2025). Meeting these requirements would be particularly challenging for developing nations.

A fundamental question is whether the value of recovered material justifies the cost and complexity. Adult diapers consist of polyester, polyethylene (PE), polypropylene (PP), bleached wood pulp, superabsorbent polymer (SAP), and various adhesives. Among these, only PE and PP hold clear economic value in mechanical recycling, while the remaining soiled SAP is typically destined for incineration or landfill. This low-value yield explains why the Knowaste process, a pioneering recycling project for AHP waste among other plastic wastes in the United Kingdom, operated for a decade before closing after government funding ceased. The scale of the recycling challenge is considerable; only 0.2% of diapers are currently recycled in the United Kingdom, despite dozens of proposed technologies (Bischof, 2024). No single process is capable of treating all AHP components. The general recycling process combines steps including separate collection, sterilization, washing, chemical soaking, and stratification, consuming significant energy, water, detergents, and chemicals while generating substantial secondary wastes. Moreover, the recovery of individual AHP components is only partial and often compromised by contamination from other constituents, a challenge shared with mixed plastic waste recycling. A key economic consideration is whether the output justifies this intensive input. The Knowaste process illustrates this dilemma well: plastics and cellulose could be recovered, but the SAP fraction had no viable market at the time and was sent for incineration (Bischof, 2024). This reflects a broader challenge: even when technical separation is achieved, finding markets for all recovered components is not guaranteed. The facility's eventual closure underscores that recycling viability depends not only on technical capability but also on sustained economic feasibility and consistent fiscal support.

More recent research has opened alternative pathways for recovered materials that shift the focus from closed-loop recycling to material conversion and downcycling. Endo et al. (2023) demonstrated that diaper ash and calcium recovered from SAP can be effectively used as soil amendments, improving plant growth and calcium uptake in agricultural soils. This approach repurposes the material rather than returning it to diaper manufacturing. Other innovations have shown conversion of recovered from SAP sodium polyacrylate to pressure-sensitive adhesives (Chazovachii et al., 2021; Li et al., 2023) or gasification to chemical feedstocks (BASF et al., 2025). While these pathways represent progress in valorizing AHP waste, they illustrate distinct forms of material conversion or downcycling rather than closed-loop recycling back into new diapers. This distinction is important for assessments of expectations and circularity that recycling can achieve for this waste stream. The recovery of SAP, the core functional component comprising up to 60% of an adult diaper by mass, is complicated by its material structure. SAP is heavily cross-linked preventing reversible melting and therefore cannot be processed through conventional mechanical recycling. This inherent property presents a fundamental barrier that no amount of sorting or cleaning can overcome. The industrial scale cost of SAP recovery is unknown, as no technology has yet reached sufficient maturity for commercial application (Somers et al. 2021).

So far only a study by Ishii et al., (2021) claimed recovery of high-grade pulp portion suitable for reuse in new diaper manufacturing from adult diaper waste in laboratory scale study. However, scaling up such

innovations to handle the volume and heterogeneity of real-world waste remains a significant challenge. The gap between bench-scale success and industrial implementation involves fundamental questions of economic viability, infrastructure compatibility, and market demand for recovered materials. This gap is particularly consequential for a waste stream that continues to grow while recycling infrastructure remains underdeveloped.

A policy disconnect is also evident: while European Union regulations favor recycling, no operational large-scale AHP waste recycling plants currently exist (Bishop et al., 2025). Available cost estimates suggest a relatively small gap between recycling and incineration: €64.24 million compared to €69.17 million. However, the difference alone may not justify the technological and infrastructural leap required (Bishop et al., 2025). Projections of carbon reduction through recycling are often optimistic, with costs sometimes escalating upon implementation. This raises questions about the overall logic of pursuing high-cost recycling for what may be minimal material yield. Future market trends may further shape the recycling landscape. In aging societies such as Japan, diaper design is evolving toward lighter, more easily separated components, which can facilitate disposal and incineration (Kawai et al., 2023). This trend mirrors the single-use plastics paradigm, where design for lightweight convenience can reduce recyclability and increase processing costs.

A particularly promising direction is medium-scale, localized treatment, such as the Taiwanese process using a proprietary "Green Fairy" detergent enabling recycling of diaper components at a smaller scale. Although, the recovered materials are typically downgraded to lower-grade applications or refuse-derived fuel rather than being reused in new diapers (Hwang et al., 2022). Local context models are manageable and adaptable, and their potentially lower environmental footprint may offer a more sustainable and replicable template for many regions compared to massive centralized plants.

In summary, while large-scale AHP recycling faces substantial barriers, ongoing research into material conversion and localized treatment offers alternative pathways worth exploring. The choice of approach depends on local context, infrastructure, and economic conditions rather than any single universal solution.

## 7. Pragmatic Solutions and Future Directions

The analysis presented in this review points toward a shift from problem identification to actionable strategy. The escalating crisis of adult diaper waste cannot be resolved by waiting for ideal solutions such as universal recycling or fully biodegradable AHPs materials. What is needed is an approach built on regulatory reform, technological realism, and consolidated efforts with shared responsibility at national and international levels.

The framework outlined below emerged directly from the thematic synthesis of the reviewed literature. Regulatory failure, consumer awareness gaps, and technological barriers to recycling were recurring themes across the analyzed studies, pointing to the need for an integrated approach that addresses all three dimensions simultaneously. A logical starting point is regulatory reclassification. If adult diapers were legally recognized as non-biodegradable plastic waste, this could pave the way for an outright ban on landfill disposal. Such ban would ideally be coupled with mandates for source-separation and supported by dedicated collection systems. Together, these measures would create the regulatory foundation for a managed waste stream. Equally important is consumer education. Regulatory changes are most effective when reinforced by public awareness. The public would benefit from clear labeling that explains the product's synthetic composition and the need for separate disposal. Just as society has learned to recognize plastic pollution, it must now understand that human excreta do not render a diaper biodegradable, any more than food residue transforms a plastic container.

The pursuit of perfect recycling has proven economically and technically infeasible at scale, while focusing on biodegradability can be misleading given the exponential growth of AHP waste. Presently, more pragmatic priority is the complete destruction of AHP waste with energy recovery. As Gu et al. (2023) pointed that the WtE pathway is already superior to continued landfilling of AHP waste. Modern WtE incineration plants, as implemented in the European Union and Japan, currently represent the most established Best Available Technology. Its primary drawback of greenhouse gas emissions can be directly mitigated by integrating Carbon Capture, Utilization, and Storage (CCUS) technologies. This approach is recognized as essential for decarbonizing the waste sector (IEA, 2022) and has been demonstrated at operational facilities such as the Klemetsrud WtE plant (Fagerlund et al., 2021). The integration of Waste-to-Energy (WtE) with Carbon Capture, Utilisation, and Storage (CCUS) reframes waste disposal as proactive carbon management, advancing SDG 13 (Climate Action). At the same time, growing climate literacy and environmental awareness among consumers are driving tangible behaviour changes, including stronger support for reforestation, tree-planting

initiatives, and low-carbon consumption choices. Nevertheless, no single technological or behavioural solution is universally applicable across all contexts.

Complementary processes such as scalable pyrolysis and gasification offer valuable alternatives, particularly where large-scale incineration infrastructure is not feasible. Pyrolysis, for instance, can be deployed at smaller scales and has been successfully applied in Japan and Taiwan for treating specific waste streams, producing carbon-rich by-products such as char, oil, and syngas (Kwon et al., 2023). The choice of technology, therefore, should be guided by local waste volumes, existing infrastructure, and financial capacity rather than a one-size-fits-all model.

Implementing such approaches globally, especially in developing nations, would benefit from a cooperative framework. Modular, scalable plant designs could be developed to suit different contexts. Funding might be structured as a hybrid model: manufacturers could bear significant financial responsibility through enforced Extended Producer Responsibility (EPR) schemes, with contributions proportional to profit. The principle of EPR could be extended to explicitly include the financing of post-consumer waste treatment. Climate finance mechanisms, such as the Green Climate Fund, offer potential vehicles for supporting such investments, given that WtE-CCUS projects align with climate mitigation objectives. This reflects a combination of stringent policy with incentives for proper disposal, a blend sometimes described as a "carrot and stick" approach. An international consortium could help oversee such efforts, facilitating technology transfer and funding management.

Multilateral development banks could also play a catalytic role in risk minimization of initial investments, enabling local governments or private operators to build capacity incrementally.

Meanwhile, long-term research into new materials should continue, but alongside, not instead of, the deployment of available solutions. The pragmatic concept proposed in this review is illustrated in Figure 2. It is based on three pillars: regulation to divert waste from landfills, education to ensure compliance, and advanced thermal treatment with carbon management to eliminate polluting substances. Implementing this approach would require consolidating political will, consumer responsibility, and economic resources worldwide, moving toward sustainable management practices (SDG 11) and environmentally sound management of chemicals and all wastes (SDG 12).


**Figure 2.** Proposed pragmatic framework for the global adult diaper waste crisis (author's own work)

# 8. Conclusion

This critical review has systematically examined the persistent and growing crisis of adult diaper waste, moving beyond quantifying the problem to critically evaluating the viability of its most commonly proposed solutions. The analysis has shown that the core impediments are not solely technological but fundamentally systemic: a regulatory gap that fails to classify adult diapers as the non-biodegradable plastic waste they are, a significant lack of consumer awareness regarding diaper composition and environmental persistence, and the economic challenges facing currently proposed technological processes.

The well-intentioned yet protracted pursuit of material substitution and ideal recycling has, in practice, become a costly diversion, delaying the consolidation of efforts around available and effective waste management solutions. The path forward therefore requires pragmatic action: decisive policy shifts to ban landfill disposal and mandate source-separation, coupled with robust consumer education.

Technologically, a diversified approach is warranted. Where centralized infrastructure exists, Waste-to-Energy incineration integrated with Carbon Capture, Utilization, and Storage (WtE-CCUS) offers a mature, proven pathway for complete waste destruction with managed carbon emissions. Where contexts differ, installations of flexible, scalable thermal technologies suitable to smaller municipalities or decentralized applications can be implemented. The choice of technology should be guided by local waste volumes, existing infrastructure, and financial capacity rather than a single prescribed model.

This transition would benefit from the enforceable extension of Extended Producer Responsibility, mobilizing manufacturers to fund the waste management infrastructure their products necessitate. Climate finance mechanisms, such as the Green Climate Fund, and catalytic investments from multilateral development banks could support such efforts, particularly in developing nations.

At the heart of these financing challenges lies a common assumption that poorer countries cannot afford modern technologies. Since plastic pollution is a global problem, the developing nations bear a disproportionate share of its impacts. This calls for a new approach to financing that shifts the focus from whether developing countries can afford advanced technologies to whether the global community can afford to continue a system in which the most vulnerable communities shoulder the environmental costs of goods produced for global consumption. Such a shift is not merely a waste management upgrade but a necessary step toward achieving interconnected Sustainable Development Goals: SDG 12 (Responsible Consumption and Production), SDG 11 (Sustainable Cities), and SDG 13 (Climate Action). A move from protracted discussion to coordinated implementation is warranted, where regulatory will, technological pragmatism, and shared financial responsibility converge to address this rapidly growing waste stream.

Research Limitations

However, several limitations of this review should be acknowledged. First, the exclusion of non-English articles and the focus on peer-reviewed literature may introduce language and publication bias. Second, the relatively small number of 20 reviewed studies reflects the under-researched nature of adult incontinence product waste specifically and may not fully capture evolving trends in this area. Third, the review focused on dedicated management pathways for adult diaper waste, which led to the exclusion of studies involving co-digestion with other organic wastes. Consequently, some alternative treatment pathways are not assessed in this review. In addition, during the research process, hurdles encountered included the scarcity of dedicated literature on adult diaper waste, which required extending the search to grey literature, and the lack of standardized terminology across the field, which necessitated testing multiple keyword combinations.

# 9. Recommendations

Future research on AHP waste management could be extended in several directions. As more empirical data become available, systematic reviews with meta-analysis may offer valuable insights. Analysis of emerging recycling technologies would benefit from access to industry data, while comparative analyses of regional regulatory frameworks could be strengthened through integration with legal and policy databases. Such efforts would benefit from collaborative, well-supported partnerships across academia, industry, and government. With continued research attention and funding, it may be possible to support policy changes for landfill diversion and the development of more sustainable technologies. We hope this review will attract researchers and enable larger funding allocations to advance these goals.

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**Data availability** The data supporting this review are available in the cited articles. The Excel file documenting the screening process is available from the corresponding author upon reasonable request.

# Declarations

**Competing Interests** The authors declare no competing interests.



**AI Use** During the preparation of this work, the authors used AI tool DeepSeek to assist with grammar and syntax editing. After using it, the authors reviewed and edited the content as needed and take full responsibility for the intellectual content, critical analysis, and conclusions of this work.

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# Appendix

## Graphical Abstract


## List of Abbreviations

| | |
|---|---|
| AHP | Absorbent Hygiene Product(s) |
| CCUS | Carbon Capture, Utilization, and Storage |
| EPR | Extended Producer Responsibility |
| GHG | Green House Gases |
| LCA | Life Cycle Assessment |
| PE | Polyethylene |
| PP | Polypropylene |
| SAP | Super Absorbent Polymer |
| SWM | Solid Waste Management |
| WtE | Waste-to-Energy |