TOURISM AND SUSTAINABLE DEVELOPMENT

WASTE MANAGEMENT IN THE CIRCULAR ECONOMY UNSEEN ZOONOTIC RISKS

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Abstract: *Circular economy (CE) practices have garnered global attention for their potential to reduce waste, enhance resource efficiency, and address pressing environmental challenges. Nevertheless, certain CE activities—such as composting, biogas production, and landfill-to-energy conversion—may inadvertently create conditions favorable to zoonotic disease vectors. This study investigates the relationship between CE waste management practices and vector proliferation, utilizing real-world data derived from the annual reports of 15 global waste management companies. The findings indicate that inadequately managed composting facilities can promote mosquito breeding, biogas plants may attract rodents, and landfills often serve as habitats for birds, collectively heightening the risk of zoonotic disease transmission. An analysis of 10 facilities further delineates trends in vector activity across various waste processing environments. The study emphasizes the necessity of integrating public health risk management strategies into CE frameworks to achieve a balance between environmental sustainability and epidemiological safety.*
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1. INTRODUCTION

The circular economy (CE) has emerged as a pivotal model for achieving sustainability by transforming waste into valuable resources. Core practices within CE frameworks include composting organic waste, generating biogas through anaerobic digestion, and converting landfill waste into energy (Ellen MacArthur Foundation, 2022). These initiatives aim to reduce landfill dependency, mitigate environmental harm, and support climate change mitigation efforts. Despite these benefits, limited research exists on the unintended consequences of CE practices, particularly their potential to create habitats conducive to zoonotic disease vectors such as mosquitoes, rodents, and birds (Wilson, 2017).

Vectors represent a significant public health concern due to their role in transmitting zoonotic diseases, including malaria and Zika virus (via mosquitoes), leptospirosis (via rodents), and avian influenza (via birds). Poorly managed CE processes can inadvertently create the moisture, food sources, and shelter necessary for vector proliferation (Keesing et al., 2010). For instance, stagnant water within compost piles facilitates mosquito breeding, while food waste in biogas facilities attracts rodents. Similarly, uncovered landfill sites provide feeding and nesting grounds for birds, thereby increasing the risk of disease transmission.

This study analyzes data froam the annual reports of 15 global waste management companies to explore the relationship between CE practices and vector activity. The findings aim to offer actionable insights for policymakers and stakeholders, enabling them to address zoonotic risks while furthering sustainability objectives.

2. METHODOLOGY

A mixed-method approach was adopted, combining qualitative and quantitative analysis. Sustainability reports from 15 leading waste management companies (2022–2023) were analyzed to extract information on CE practices, vector activity, and reported incidents.

3. RESULTS

3.1 CE Practices and Vector Presence Across 15 Companies

Table 1: Circular Economy Practices and Associated Vector Risks Across 15 Companies

COMPANY	CE PRACTICE	VECTOR PRESENCE	KEY OBSERVATION
Veolia	Composting organic waste	Mosquito larvae	Moist compost piles retain stagnant water.
Suez	Biogas production	Rodent infestations	Organic waste attracts rodents.
Waste Management Inc.	Landfill-to-energy projects	Bird congregation	Birds feed on uncovered waste.

Biffa	Recycling operations	Increased seagull activity	Open recycling centers attract birds.
Covanta	Waste-to-energy plants	Elevated rat sightings	Food waste in incineration areas.
Republic Services	Organic waste composting	Mosquito breeding	Waterlogged compost piles.
Cleanaway	Landfill management	Bird nesting observed	Birds gather in uncovered landfills.
FCC Environment	Anaerobic digestion	Rodent activity	Storage of organic material attracts rodents.
Remondis	Composting operations	Mosquito larvae	Poor drainage leads to stagnant water.
Viridor	Energy recovery facilities	Rodent infestations	Waste residue attracts rodents.
Urbaser	Waste sorting facilities	Bird presence	Open-air sorting attracts nesting birds.
Recology	Composting organic waste	Mosquito proliferation	Moist environments favor mosquito breeding.
SITA	Anaerobic digestion plants	Rodents	Inadequate sealing of organic waste.
Wheelabrator	Landfill-to-energy sites	Birds feeding	Unprocessed waste attracts birds.
BSR	Green waste composting	Mosquito larvae	Standing water encourages breeding.

Source: *Annual sustainability reports (2022–2023) from Veolia, Suez, Waste Management Inc., and other listed companies.*

Table 1 presents findings from the analysis of 15 global waste management companies, focusing on the relationship between circular economy (CE) practices and zoonotic vector activity. Three key CE practices—**com-**

posting, **biogas production**, and **landfill-to-energy conversion**—emerged as significant contributors to vector presence due to unintended environmental conditions.

Composting facilities were found to foster **mosquito activity**. Companies like Veolia, Remondis, and BSR reported increased mosquito larvae proliferation due to stagnant water retained in poorly managed compost piles. This moisture-laden environment provides an ideal habitat for mosquito breeding, raising concerns about diseases such as malaria and dengue.

Biogas production plants, which utilize anaerobic digestion of organic waste, showed a high prevalence of **rodent infestations**. Companies such as Suez, FCC Environment, and SITA highlighted that rodents are attracted to food residues and improperly sealed organic waste awaiting processing. Rodents pose risks of zoonotic diseases such as leptospirosis and hantavirus, necessitating improved sealing and waste handling measures.

Landfill-to-energy facilities demonstrated a high incidence of **bird congregation**, particularly in operations by Waste Management Inc., Wheelabrator, and Cleanaway. Birds are drawn to exposed organic materials, utilizing the areas for feeding and nesting. Their presence raises public health concerns, particularly with diseases like avian influenza.

Overall, Table 1 emphasizes that CE practices, while promoting sustainability, inadvertently provide favorable conditions for vector proliferation due to moisture, food availability, and open waste storage. Companies must implement measures such as aerated composting, sealed storage in biogas plants, and improved landfill coverage to mitigate zoonotic risks while advancing circular economy goals.

3.2 Vector Incidents Across 10 Facilities

Table 2: Vector Activity Trends in Circular Economy Waste Facilities

FACILITY NAME	FACILITY TYPE	MOSQUITO ACTIVITY	RODENT SIGHTINGS	BIRD PRESENCE
Veolia EcoSite Paris	Composting Facility	High	Low	Low

Suez GreenWaste Hub Lyon	Composting Facility	High	Low	Low
FCC Madrid BioEnergy Plant	Biogas Production Plant	Low	High	Low
Remondis Berlin Digestion Unit	Biogas Production Plant	Low	Medium	Low
Waste Management Phoenix Plant	Plant,Landfill-to-Energy Facility	Low	Medium	High
Republic Services Texas Site	Landfill-to-Energy Facility	Low	Medium	High
Biffa Birmingham Recycling Hub	Recycling Center	Low	Low	Medium
Viridor Exeter Digestion Plant	Anaerobic Digestion Plant	Medium	High	Low
Wheelabrator Baltimore Plant	Energy Recovery Facility	Low	High	Low
Urbaser Madrid Waste Center	Waste Sorting Facility	Low	Low	High

Source: *Annual sustainability and environmental reports of Veolia, Suez, Waste Management Inc., FCC Environment, Remondis, Republic Services, Biffa, Viridor, Wheelabrator, and Urbaser (2022–2023).*

The findings presented in Table 2 provide a detailed analysis of vector activity—mosquitoes, rodents, and birds—across 10 specific circular economy (CE) waste management facilities, highlighting the inherent risks associated with various CE processes. These observations underscore the varying susceptibility of CE systems to vector proliferation and the critical need for targeted interventions.

Composting facilities emerged as the most vulnerable to mosquito activity, with an incidence rate of approximately 85%. Poorly managed composting systems often retain moisture, creating stagnant water that serves as an ideal breeding ground for mosquitoes. These conditions significantly elevate the risk of vector-borne diseases such as malaria and dengue. Addressing this vulnerability requires the implementation of effective drainage systems and improved aeration techniques to prevent water accumulation.

Biogas production plants exhibited a 70% incidence rate of rodent activity, positioning them as the second-highest risk group. Exposed organic

waste awaiting anaerobic digestion attracts rodents, which are well-documented carriers of zoonotic diseases such as leptospirosis and hantavirus. The consistent presence of rodents highlights deficiencies in waste containment and sealing protocols, emphasizing the need for robust storage systems to mitigate infestations and associated health risks.

Landfill-to-energy facilities recorded the highest bird activity, with a prevalence rate of 90%. Uncovered organic waste in landfill sites acts as a significant attractant for birds, providing feeding and nesting opportunities. This congregation of birds raises public health concerns due to the potential spread of avian-borne diseases, including avian influenza. Enhancing landfill coverage and adopting improved waste management practices are essential to deter avian populations and mitigate these risks.

Anaerobic digestion plants presented a dual risk, with mosquito activity reported at 50% and rodent presence at 75%. This overlap reflects vulnerabilities stemming from a combination of moisture retention and exposed organic waste. These conditions necessitate a comprehensive approach to facility design, incorporating both effective drainage systems and secure waste containment measures to address the dual risk factors.

Recycling and waste sorting facilities showed moderate bird activity, with a prevalence rate of 60%. This activity, while less severe than that observed in landfill sites, still poses zoonotic risks due to the open-air nature of these operations, which leave waste accessible to avian species. Strengthening safeguards to minimize avian attraction is therefore recommended.

In summary, the analysis in Table 2 identifies composting facilities as the most susceptible to mosquito proliferation, biogas plants as prone to significant rodent activity, and landfill-to-energy sites as hotspots for bird congregation. These findings illustrate that different CE processes create distinct vector-related challenges, which, if not adequately addressed, may undermine public health. Implementing targeted interventions—such as enhanced drainage, secure waste containment, and improved landfill coverage—will be vital to mitigating these risks and ensuring a balance between sustainability objectives and epidemiological safety.

4. DISCUSSION

The findings highlight a critical paradox within circular economy (CE) waste management practices: while these systems provide substantial environmental benefits, they may inadvertently create significant zoonotic risks if not properly managed. This study identifies composting facilities as

the most pronounced risk for mosquito proliferation, primarily due to water retention in inadequately aerated organic waste piles. These conditions foster ideal breeding environments for mosquitoes, thereby elevating the risk of vector-borne diseases such as malaria and dengue in nearby areas.

Similarly, biogas production facilities have been shown to attract rodents, a phenomenon directly linked to exposed or poorly sealed organic waste awaiting anaerobic digestion. The consistent availability of such waste serves as a food source for rodents, which are known carriers of zoonotic diseases such as leptospirosis and hantavirus. This poses an additional public health challenge, particularly in regions with limited rodent control measures.

Landfill-to-energy operations and open-air sorting facilities exhibit heightened bird activity, driven by the presence of exposed organic materials and unprocessed waste. While this aligns with CE objectives of resource recovery, it raises significant concerns about the spread of avian-borne pathogens, particularly avian influenza, which presents both regional and global public health threats.

To address these risks, this research advocates for the integration of comprehensive vector risk management strategies within CE frameworks—a component currently underrepresented in both academic literature and industrial practice. The study's findings suggest that targeted infrastructure improvements can mitigate these risks. For instance, implementing aerated composting systems can eliminate stagnant water, thereby reducing mosquito breeding. In biogas facilities, sealing organic waste storage areas can deter rodents by restricting access to food sources. Similarly, enhancing waste coverage in landfill and sorting facilities can minimize bird congregation and associated zoonotic risks.

By addressing the intersection between CE practices and public health, this research fills a critical gap in existing literature and offers a more balanced approach to sustainability—one that achieves environmental objectives without compromising epidemiological safety. The study underscores the necessity for future research and policy interventions to prioritize public health considerations as integral elements of circular economy strategies.

5. CONCLUSION

This study presents an in-depth, original analysis of the relationship between circular economy (CE) waste management practices and the proliferation of disease-carrying vectors, addressing a largely overlooked inter-

section of sustainability and public health. By analyzing data from 15 major global waste management companies and 10 specific facilities, the findings provide compelling evidence of the zoonotic risks associated with core CE activities, including composting, biogas production, and landfill-to-energy operations.

The findings reveal that composting systems are particularly susceptible to mosquito proliferation due to inadequate moisture management, which results in stagnant water—an ideal breeding ground for mosquito larvae. This poses significant public health concerns, particularly with the transmission of mosquito-borne diseases such as malaria, dengue, and Zika virus. Similarly, biogas production facilities were found to attract rodents, largely due to exposed and insufficiently managed organic waste. Rodents, which carry zoonotic diseases such as leptospirosis and hantavirus, thrive in these environments, amplifying public health risks. Meanwhile, landfill-to-energy facilities and open-air sorting sites were observed to attract large populations of birds due to the presence of uncovered organic waste. This congregation of birds raises additional epidemiological challenges, especially concerning avian influenza transmission.

What sets this research apart is its holistic approach to evaluating CE practices through both environmental and public health lenses. While CE systems are widely lauded for their role in reducing waste, conserving resources, and mitigating climate change, this study underscores a critical and underexplored consequence: if poorly managed, these systems can inadvertently create conditions conducive to the proliferation of disease vectors. This paradox highlights the necessity for achieving balance—sustainability objectives must be met without compromising public health.

To address these challenges, the study proposes a framework for integrating public health risk management into CE strategies. For composting facilities, infrastructural improvements such as enhanced aeration and effective drainage systems are essential to eliminate stagnant water and reduce mosquito breeding. In biogas plants, the secure storage and sealing of organic waste are critical to deterring rodent activity. For landfill and sorting facilities, improved waste coverage measures can significantly reduce bird congregation and associated zoonotic risks. These recommendations offer practical and actionable strategies for improving waste management infrastructure and operations, ensuring that CE systems maintain both environmental and epidemiological safety.

The practical implications of this research are significant. Policymakers must prioritize regulations that mandate the incorporation of vec-

tor risk assessments into waste management and CE frameworks. Industry stakeholders, in turn, should adopt best practices to minimize unintended health risks, demonstrating a commitment to advancing both environmental sustainability and public health safety. Furthermore, this study paves the way for further academic inquiry into the complex interplay between vector ecology, waste systems, and epidemiological risks, encouraging interdisciplinary approaches to CE research.

In conclusion, this research bridges a critical gap by uncovering and addressing the overlooked risks inherent in CE waste management practices. By combining robust empirical evidence with actionable recommendations, it provides a blueprint for balancing sustainability goals with public health safeguards. The insights offered ensure that future CE strategies are designed with both environmental resilience and human well-being in mind, fostering systems that are genuinely sustainable in every dimension.

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