

Orchestrating Sustainable Waste Management: A Pentahelix Collaborative Governance Model in Resource-Extraction Regions

Wahyudin Noor¹, I Nyoman Sudayana², Heriamariaty², Johanna Maria Rotinsulu²



¹ Postgraduate Program, University of Palangka Raya, Indonesia

² University of Palangka Raya, Indonesia

Correspondence should be addressed to:
Wahyudin Noor
wahyudinnoo76@gmail.com

Abstract:

Rapid urbanization and aggressive mining and plantation expansions in East Barito Regency have severely complicated regional waste management systems. This study analyzes the strategic role of local government and identifies the critical factors that shape participatory policy models for designing an effective waste management framework. Researchers employed a mixed-methods sequential explanatory design integrating Structural Equation Modeling-Partial Least Squares, SWOT analysis, and the Analytic Hierarchy Process. Quantitative results demonstrate that environmental awareness, community participation, economic incentives, social dynamics, and private sector engagement significantly and positively influence sustainable waste management policies. Environmental factors emerge as the most dominant predictor of policy success within this specific industrial context. The local government functions simultaneously as a regulator, facilitator, coordinator, motivator, and evaluator to drive systemic transformation. Implementing community-based waste banks, circular economy initiatives, and Corporate Social Responsibility funding substantially amplifies active public participation. The research ultimately produces a novel participatory policy model grounded in collaborative governance and a comprehensive pentahelix approach. This integrated framework unites local authorities, residents, private enterprises, academics, and the media to deliver a sustainable waste management system tailored to resource-extraction regions. The proposed model provides actionable policy recommendations for regional authorities aiming to mitigate severe ecological deficits while fostering robust community empowerment and long-term environmental resilience.

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INTRODUCTION

Global waste generation has escalated into a critical environmental crisis driven by rapid urbanization, industrial expansion, and shifting global consumption patterns (Lu et al., 2024). The continuous accumulation of solid waste severely degrades soil, water, and air quality while exacerbating public health risks across diverse ecosystems (Choudhary et al., 2024). International environmental frameworks increasingly mandate a transition from conventional disposal methods to sustainable paradigms that emphasize reduction, reuse, and recycling (Shukla & Khan, 2022). Achieving these global sustainability goals requires moving beyond purely technical interventions to embrace holistic, community-integrated management strategies that address the multifaceted nature of modern ecological challenges. Such systemic transitions are essential for mitigating the severe ecological footprints left by expanding human settlements (Gao et al., 2026).

East Barito Regency in Central Kalimantan, Indonesia, exemplifies this escalating crisis through its unique intersection of demographic shifts and aggressive industrial expansion. Booming mining operations and large-scale plantation developments have exponentially increased waste volumes, completely overwhelming the region's limited landfill capacities and basic collection infrastructure. This severe infrastructure deficit forces residents to resort to improper disposal practices, resulting in massive waste accumulation along riverbanks and triggering recurring seasonal flooding. The prevailing technical-operational approaches fail to address these compounding ecological threats, underscoring an urgent need for systemic policy reform tailored to the region's specific industrial and demographic realities (Murthy & Ramakrishna, 2022).

Contemporary environmental governance increasingly advocates collaborative frameworks that integrate circular economy principles and multi-stakeholder participation to transcend traditional management limitations. Current academic and practical discourses emphasize that sustainable waste management requires active engagement from diverse actors, including local authorities, private enterprises, academic institutions, and civil society (Ali et al., 2023). The integration of corporate social responsibility initiatives with community-based recycling programs represents the cutting edge of modern environmental policy (Anyanwu et al., 2025). These advanced collaborative models clearly demonstrate that empowering local communities and leveraging private-sector resources can significantly enhance the efficiency and long-term sustainability of regional waste management systems (Leknoi et al., 2024).

Existing literature predominantly focuses on urban technical solutions or isolated social interventions, leaving a critical void in understanding how local governments can orchestrate participatory policies in resource-extraction regions. Previous studies frequently treat environmental, social, and economic variables in isolation, failing to capture the complex synergistic dynamics required for holistic policy formulation (Garg & Arora, 2025). Current research rarely addresses the specific governance challenges faced by regencies undergoing rapid industrialization amid severe infrastructural deficits (Rengerla & Angamuthu, 2025). This theoretical and empirical gap obscures the precise mechanisms through which local governments can effectively mobilize diverse stakeholders to co-create sustainable environmental solutions in highly specialized industrial contexts.

This study introduces a novel participatory policy model anchored in collaborative governance and a pentahelix approach, specifically tailored to the complex waste dynamics of mining and plantation areas. The research uniquely integrates structural equation modeling with strategic analyses to quantify the precise influence of environmental, social, economic, and institutional factors on policy success (Yang et al., 2025). Positioning the local government as the central orchestrator of a multi-stakeholder ecosystem allows the proposed framework to transcend conventional top-down regulatory models. This innovative synthesis provides a comprehensive, context-specific blueprint for transforming waste management from a fragmented operational task into a cohesive, community-driven ecological strategy (Reni & Prasetyo, 2025).

The primary objective is to analyze the multifaceted factors shaping local government roles and to design an integrated, sustainable waste management framework that addresses the urgent infrastructure and ecological deficits in East Barito. The escalating volume of industrial and domestic waste demands immediate, evidence-based policy interventions to prevent irreversible environmental degradation and protect vulnerable public health (Diamond et al., 2024). Understanding the dominant variables driving community participation and private-sector engagement is critical to formulating effective regional strategies. Addressing this urgent policy need will ensure that waste management initiatives are both scientifically robust and practically applicable to the regency's unique socio-ecological landscape (Nieves et al., 2022).

Implementing this comprehensive model will provide actionable policy recommendations for regional authorities while enriching theoretical discourses on collaborative environmental governance in developing industrial zones (Song et al., 2025). The findings offer practical guidelines for local governments to optimize resource allocation, enhance cross-sectoral coordination, and foster robust community empowerment initiatives. The research provides empirical validation of the pentahelix collaborative governance theory in the specific context of resource-dependent regional economies (Pramesti & Rukmana, 2025). This integrated approach promises to catalyze a transition toward a circular economy, ensuring long-term ecological resilience, economic empowerment, and improved quality of life for the local population (Aiguobarueghian et al., 2024). Future applications of this framework will undoubtedly guide other resource-dependent regions toward sustainable environmental stewardship.

METHOD

Design

This research employed a mixed-methods approach with a sequential explanatory design. The quantitative phase was conducted first to measure relationships among variables. The qualitative phase was followed to strengthen and explain the quantitative findings. This approach provided a deeper understanding of participatory policies in sustainable waste management within the study area.

Setting and Time

The research took place in East Barito Regency, Central Kalimantan Province. Researchers selected this location due to the increasing volume of waste generation and limited waste management infrastructure. The study also addressed the urgent need for participatory policy models that emphasize the role of local government. The research activities occurred during the 2025–2026 period.

Population, Sample, and Sampling

The quantitative population comprised the people of East Barito Regency involved in or affected by the regional waste management system. Researchers used purposive sampling to ensure that respondents understood the state of waste management in the study area. The qualitative phase involved key informants, including local government officials, community leaders, waste bank managers, academics, business actors, environmental communities, and the general public. The research team purposively selected these informants for their expertise in sustainable waste management.

Instrument and Measurement Properties

The research comprised several key variables, including environmental, social, and economic factors; community participation; the roles of the private sector and local government; and sustainable waste management policies. The research team validated the quantitative data through rigorous tests of instrument validity and reliability. Qualitative data were validated through source triangulation, method triangulation, member checking, peer discussion, and audit trails to ensure trustworthiness.

Data Collection Procedure

The researchers utilized multiple techniques to gather comprehensive data. Quantitative data collection involved distributing questionnaires to the selected sample. Qualitative data collection included conducting in-depth interviews and focus group discussions with key informants. The team also gathered secondary data through documentation of government regulations and official reports.

Data Analysis

Quantitative data analysis utilized the Structural Equation Modeling-Partial Least Squares (SEM-PLS) method with SmartPLS software version 3.2.9. The analytical process included outer model testing, convergent validity testing, discriminant validity testing, reliability testing, inner model testing, coefficient of determination testing, and hypothesis testing. The researchers also analyzed direct and indirect effects between variables. Additional strategic analyses included the SWOT method, Importance-Performance Map Analysis (IPMA), and the Analytic Hierarchy Process (AHP).

Ethical Declaration

The University of Palangka Raya provided ethical approval for this research. The study adhered to all ethical guidelines regarding participant consent and data confidentiality.

RESULTS

Waste management in East Barito Regency faces structural and operational challenges driven by population growth, residential expansion, and plantation activities. The region relies on conventional collection and disposal methods due to severely limited infrastructure for final disposal, transportation, and 3R processing. Public awareness is increasing, yet active community participation remains suboptimal. Residents rarely separate waste at the household level, and community-based initiatives like waste banks operate on a very limited scale.

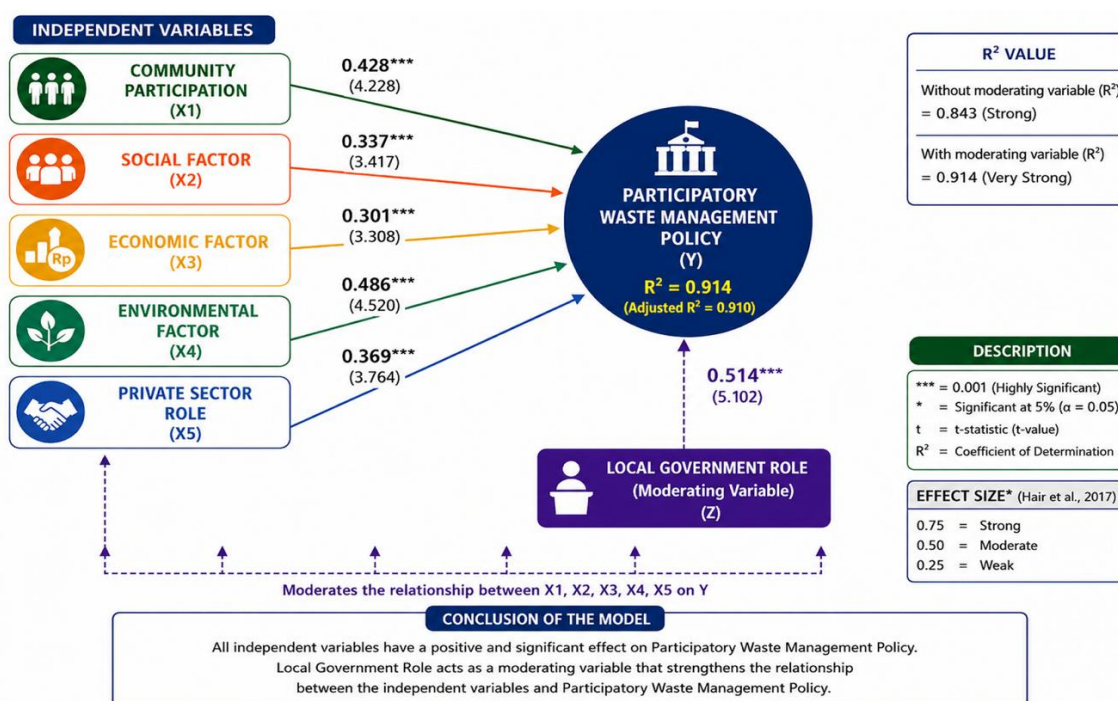


Figure 1. Inner Model of Participatory Policy Model Based on the Role of Regional Government in Waste Management in East Barito Regency

Structural Equation Modeling-Partial Least Squares (SEM-PLS) Analysis Results

The SEM-PLS analysis confirmed that environmental, social, and economic factors, alongside community participation, private-sector roles, and local government functions, are significantly related to the participatory waste management policy model in East Barito Regency. Outer model testing established construct validity and reliability, yielding Average Variance Extracted values above 0.50 and composite reliability exceeding 0.70. Inner model and hypothesis testing revealed that environmental factors exert the most dominant influence on policy success, followed by community participation and social factors. Economic variables positively drive circular economy involvement, while private-sector Corporate Social Responsibility simultaneously strengthens the regional management system. These findings highlight public environmental awareness and active community engagement as the primary drivers of effective, sustainable waste management policies.

Community Participation in Waste Management

Community participation is essential for sustainable waste management, encompassing activities such as household waste sorting, cleanups, plastic reduction, waste bank management, and environmental education. Participation levels depend heavily on education, environmental knowledge, the availability of facilities, government support, and economic benefits. Insufficient education and outreach often lead residents to view waste management solely as a government responsibility. Interviews and focus group discussions reveal that active community involvement significantly increases when supported by adequate facilities, economic incentives, and continuous mentoring from local authorities and environmental groups.

The Influence of the Regional Government's Role in Waste Management

The regional government anchors East Barito Regency's participatory waste management model by acting as a regulator, facilitator, coordinator, motivator, and evaluator. Regulatory frameworks face implementation hurdles like limited budgets, inadequate infrastructure, and weak cross-sectoral coordination. Facilitation efforts successfully provide essential facilities, waste bank models, environmental education, and community empowerment. Long-term success requires the government to forge collaborative governance networks encompassing communities, private enterprises, academics, environmental groups, and the media. Such multi-stakeholder synergy proves essential for maximizing policy effectiveness, boosting public participation, and ensuring sustainable environmental development.

SWOT Analysis Results

The SWOT analysis results indicate that waste management in East Barito Regency has several strengths, including support from regional regulations, local government commitment, and a strong culture of cooperation among communities. Furthermore, opportunities for circular economy-based waste management models and private-sector support are strategic factors in advancing waste management. However, this study also identified several weaknesses, including limited waste management facilities and infrastructure, low public awareness of waste sorting, and suboptimal coordination among relevant agencies. Threats include increasing waste volumes due to population growth and increased mining and plantation activities.

Importance Performance Map Analysis (IPMA) Results

The IPMA analysis indicates that environmental variables are the most important factors in supporting the effectiveness of sustainable waste management policies. Furthermore, community participation and the role of local governments are strategically positioned and require continuous

performance improvement. The IPMA results indicate that the main priorities for policy improvement should focus on increasing public education and environmental awareness, strengthening waste management facilities, implementing waste bank models, enhancing cross-sectoral coordination, and strengthening the role of local governments in community oversight and development.

Analytic Hierarchy Process (AHP) Results

The AHP analysis results indicate that the priority strategies in the participatory waste management policy model in East Barito Regency include strengthening waste management institutions, increasing the capacity of final disposal sites (TPA), a community-based waste bank model, community education and empowerment, strengthening collaboration between local governments and the private sector through Corporate Social Responsibility (CSR), and an environmentally-based circular economy system model. These strategies are considered the most effective in supporting sustainable, participatory waste management, oriented toward improving environmental quality.

Participatory Policy Model for Sustainable Waste Management

Based on the overall analysis, this study successfully developed a participatory policy model for sustainable waste management that positions local governments as the primary actors in collaborative governance. This model integrates the roles of local governments, community participation, private sector support, social, economic, and environmental factors, community empowerment approaches, and the circular economy concept. The resulting model emphasizes the importance of synergy among stakeholders in creating a waste management system that focuses not only on reducing waste volume but also on improving community well-being and maintaining long-term environmental sustainability.

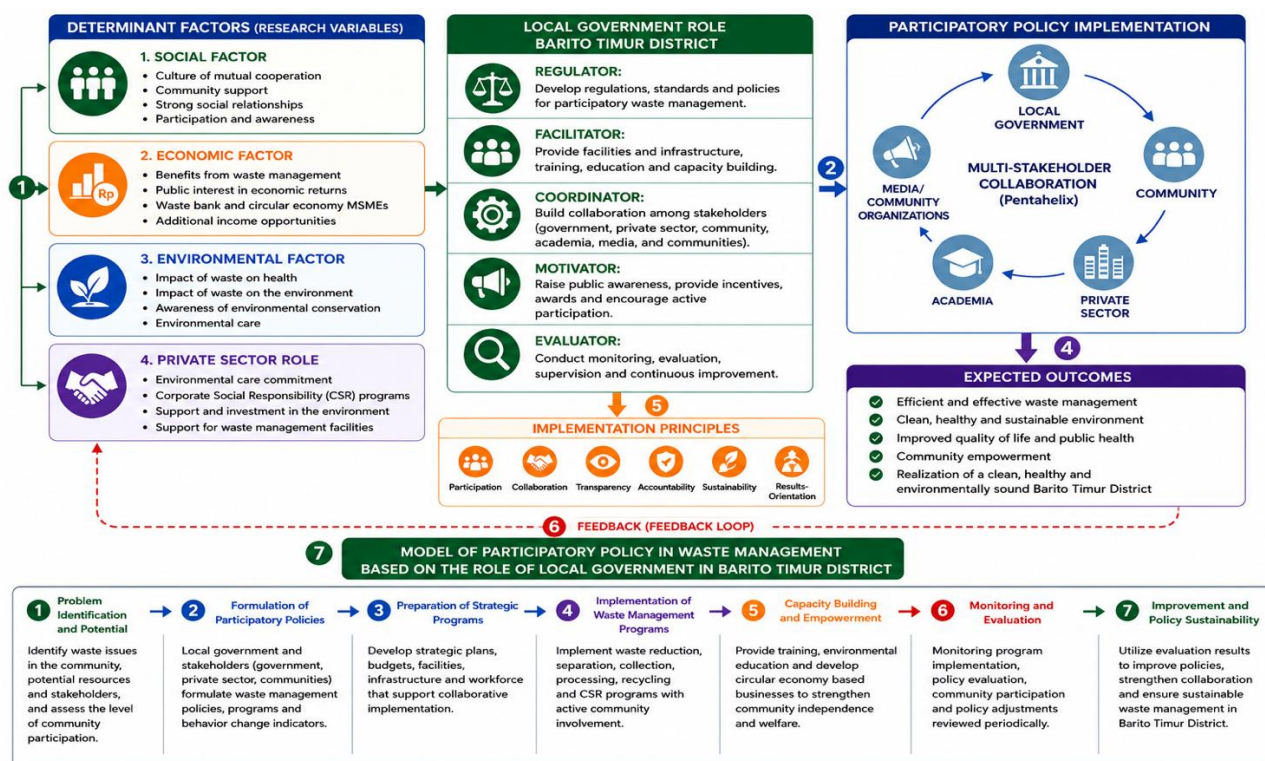


Figure 2. Participatory Policy Model in Waste Management Based on the Role of Government in East Barito Regency

DISCUSSION

The primary finding of this study establishes the local government as the central architect of a participatory waste management model in East Barito Regency. Local authorities function simultaneously as regulators, facilitators, coordinators, motivators, and evaluators to build a sustainable system that addresses complex urban and industrial challenges. Structural equation modeling results confirm that environmental factors exert the most dominant influence on policy success. Public awareness of the severe health and ecological impacts of improper waste disposal directly drives community compliance (Nuryana & Ismed, 2025). This empirical evidence underscores the necessity of integrating environmental education into core regional development strategies.

Active community participation emerges as a critical determinant for the successful implementation of sustainable waste management policies. Residents engaged in household waste sorting, environmental cleanups, and waste bank management demonstrate significantly greater ecological concern compared to passive observers. This observation strongly supports the theoretical framework of participatory governance, which posits that citizen involvement in policy planning and evaluation enhances the effectiveness of public programs. Community engagement fosters a profound sense of ownership over local environmental initiatives (Alimoradiyan et al., 2024). Such ownership guarantees the long-term sustainability of waste reduction programs beyond initial government interventions.

Social factors and local cultural dynamics profoundly influence residents' collective willingness to engage in environmental preservation. The indigenous culture of cooperation serves as a powerful catalyst for maintaining neighborhood cleanliness and organizing community-based recycling efforts across diverse districts. These empirical results align seamlessly with Putnam's social capital theory, which asserts that dense social networks, trust, and civic cooperation enhance community-based development outcomes (Poshai & Intauno, 2024). Strong social capital within East Barito Regency provides the foundational trust required for collective action. Local leaders leverage these existing social bonds to mobilize residents toward shared environmental goals.

Economic incentives and circular economy frameworks transform waste from a mere environmental burden into a valuable community resource. The establishment of community waste banks and localized recycling enterprises generates tangible household income while promoting environmentally sustainable businesses across rural and urban neighborhoods. This finding validates circular economy theory, which conceptualizes waste as an economic input rather than a terminal output (Puntillo, 2023). Effective material recovery and reuse strategies create localized green jobs. Community-based waste management, therefore, functions as a dual mechanism for ecological preservation and grassroots economic empowerment.

Private-sector engagement through Corporate Social Responsibility initiatives provides essential financial and infrastructure support for regional waste management. Mining and plantation companies possess the substantial financial resources to fund advanced sorting facilities, comprehensive environmental education campaigns, and innovative waste-to-value infrastructure. These contributions validate the necessity of a pentahelix approach that integrates government, community, private enterprise, academia, and media into a unified ecosystem. Multi-stakeholder collaboration bridges the critical funding gaps inherent in municipal environmental budgets (Muyassarrah et al., 2022). The private sector thereby transitions from a mere waste generator to an active partner in regional ecological restoration.

These empirical results align with and extend existing global literature on collaborative environmental governance in developing regions. Previous studies identify infrastructure deficits and

low civic engagement as primary barriers to effective waste management. International research consistently demonstrates that top-down, purely technical waste collection systems fail without robust community integration and localized behavioral interventions. The current study expands this knowledge by quantifying the specific dominance of environmental awareness over economic or social variables in resource-extraction contexts (Mashi et al., 2026). This comparative perspective confirms that participatory governance models are universally applicable yet require careful localized calibration to address unique regional industrial pressures.

The theoretical implications of this research significantly enrich the academic discourse on collaborative governance and participatory policy models. Integrating social capital theory with circular economy principles creates a comprehensive framework for understanding complex socio-ecological waste systems. The study demonstrates that environmental policy success depends on the synergistic interplay among ecological awareness, economic utility, and social trust. Academic literature frequently treats these variables in isolation, creating fragmented policy recommendations that fail to address the multifaceted nature of modern environmental crises (Choudhury et al., 2026). This research provides a unified theoretical model demonstrating how these dimensions interact dynamically within a pentahelix governance structure.

Practical policy implications highlight the urgent need for localized, context-specific governance strategies in resource-extraction regions. Municipal authorities must pivot from conventional collection-and-dump methodologies to integrated, community-centric circular-economy models. Local governments should prioritize expanding the capacities of final disposal sites while simultaneously decentralizing waste sorting to the neighborhood level (Sarofah et al., 2025). Policy frameworks must explicitly mandate Corporate Social Responsibility allocations toward environmental infrastructure in mining and plantation zones to ensure equitable burden-sharing. Educational campaigns must shift from basic awareness to practical, economically incentivized behavioral change programs.

Several methodological and contextual limitations must be acknowledged when interpreting the findings of this research. The cross-sectional nature of the quantitative data collection restricts the ability to establish definitive causal relationships between the identified variables. Future longitudinal studies are necessary to track how changes in environmental awareness directly impact community participation over extended periods. The geographic specificity of East Barito Regency, with its unique mining and plantation demographics, may limit the immediate generalizability of the proposed model to purely urban, agrarian, or coastal regions. Comparative studies across diverse ecological and economic zones strengthen the external validity of these findings.

Operational constraints within the regional waste management system also pose significant barriers to the immediate application of the proposed model. Severe limitations in municipal budgets, specialized transportation fleets, and advanced recycling technologies hinder the rapid scaling of community-based initiatives. Suboptimal cross-sectoral coordination between environmental agencies, public works departments, and private enterprises creates persistent administrative bottlenecks. The exponential increase in waste volume, driven by rapid urbanization and industrial expansion, continues to outpace current infrastructure capacity. Addressing these structural deficits requires sustained political commitment, massive capital investment, and innovative financing mechanisms beyond the scope of current local government capabilities.

Future research should address these limitations by employing mixed-methods longitudinal designs to capture the evolving dynamics of participatory waste management. Investigating the specific mechanisms by which Corporate Social Responsibility funds are allocated and utilized would provide deeper insights into the efficacy of private-sector governance. Scholars should also explore the role of digital technologies and smart waste management systems in enhancing cross-sectoral

coordination and public transparency. Examining the psychological and behavioral drivers of environmental compliance in heavily industrialized regions represents another critical avenue for future academic inquiry. Such investigations will refine the pentahelix model for broader global application and policy adaptation.

CONCLUSION

This study establishes the local government as the central architect of a participatory waste management model in East Barito Regency, functioning simultaneously as a regulator, facilitator, coordinator, motivator, and evaluator. Structural equation modeling confirms that environmental awareness, community participation, private-sector engagement, social dynamics, and economic incentives exert significant positive influences on policy success, with environmental factors emerging as the dominant predictor. Strategic analyses position the region for aggressive growth by leveraging strong internal community cooperation and external corporate opportunities to prioritize the development of final disposal sites, community-based waste banks, and comprehensive public education. The resulting collaborative governance framework integrates local authorities, residents, private enterprises, academics, and media into a unified pentahelix ecosystem. This integrated approach transforms waste management from a purely technical operation into a sustainable, community-empowered system capable of addressing the complex ecological challenges of resource-extraction regions.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest in the conduct of the research, preparation of the manuscript, or publication of this article. The research was conducted independently and guided by scientific objectivity, free from personal interests, institutions, or other parties that could affect the results. All data used in the research were obtained and analyzed in accordance with ethical standards.

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