

Waste Management, Environmental Health, and Community Well-being in Harbour Areas of Western Province, Zambia: AI, Smart Systems and Pathways to Sustainability

Loveness Moono*¹, Dr. Ravibaskar Ramalingam²

¹Student, DMI St. Eugene University, Zambia

²Associate Professor, DMI St. Eugene University, Zambia

Abstract — Inadequate waste management in urban and peri-urban harbour areas poses severe risks to community health, environmental integrity, and sustainable development in sub-Saharan African cities. Two selected harbour areas in Zambia's Western Province face significant solid waste management challenges that directly compromise the health and well-being of resident communities. This article examines the impacts and effects of waste management practices on people and the environment in these harbour areas, situating local empirical findings within global scholarship on smart waste management systems, artificial intelligence in environmental monitoring, blockchain-enabled waste tracking, and community-based environmental action. Findings from a descriptive survey reveal that inadequate waste collection, open burning, and unregulated dumping generate significant health burdens including respiratory illness, waterborne disease, and child malnutrition alongside environmental degradation, water contamination, and biodiversity loss. The study argues that AI-powered smart waste management systems, sensor-based environmental monitoring, and community digital reporting platforms offer transformative pathways for improving waste management outcomes in harbour communities. Policy recommendations are presented.

Keywords — Waste Management; Environmental Health; Harbour Areas; Western Province; Zambia, Artificial Intelligence; Smart Systems; Community Well-Being.

1. Introduction

The management of solid, liquid, and organic waste in rapidly urbanising communities presents one of the most pressing environmental governance challenges facing sub-Saharan African municipalities (Shanthy et al., 2025; Vettriselvan et al., 2026a). Harbour and waterfront communities face compounded waste management challenges owing to their geographic proximity to water bodies where inadequately managed waste creates direct pathways for water contamination, aquatic ecosystem degradation, and vector-borne disease transmission that affect not only local communities but downstream populations and ecosystems (Ashifa, 2020b; Ashifa, 2022). In Zambia's Western Province, harbour communities along the Zambezi River and associated waterways face these challenges acutely, with documented inadequacies in municipal waste collection, hazardous waste disposal, and community waste awareness creating persistent health and environmental risks (Vettriselvan & Anto, 2018; Kariveliparambil et al., 2026b). Global advances in AI-powered smart waste management systems, sensor-based environmental monitoring, and digital community engagement platforms offer transformative possibilities for addressing waste management challenges in communities that have historically been underserved by conventional approaches (Venice et al., 2025a; Shanthy et al., 2025). This article examines the current waste management situation in

two selected Western Province harbour areas and identifies evidence-based pathways for improvement drawing on international technology and governance best practice.

2. Literature Review

2.1 Waste Management and Community Health Impacts

The health consequences of inadequate waste management are severe, multidimensional, and inequitably distributed falling most heavily on the poorest and most marginalised community members who lack the resources to distance themselves from waste exposure (Ashifa, 2020a; Ashifa, 2022; Ranganathan et al., 2024). Open dumping and burning of solid waste generate toxic particulate matter and gaseous pollutants that cause acute and chronic respiratory illness, with children and elderly individuals particularly vulnerable due to their physiological sensitivity to air pollutants (Ashifa, 2021a; Ashifa, 2021b). Contamination of water sources through leachate from waste dumps and storm-water runoff carrying waste into waterways creates pathways for waterborne disease transmission including cholera, typhoid, and diarrhoeal diseases that cause significant morbidity and mortality in affected communities (Ashifa, 2020b; Vettriselvan et al., 2025a). The mental health consequences of living in waste-polluted environments including chronic stress, anxiety, diminished sense of place and community pride, and

feelings of governmental neglect are increasingly recognised in the environmental health literature (Zahoor et al., 2025; Elkin et al., 2025). Children who grow up in inadequately managed waste environments face compounded developmental disadvantage through nutritional impacts of waterborne illness, neurological effects of heavy metal exposure, and reduced learning capacity associated with chronic stress and ill health (Ranganathan et al., 2024; Vettriselvan et al., 2025b).

2.2 AI and Smart Waste Management Systems

Artificial intelligence is transforming waste management practice in global cities through smart collection optimisation, predictive maintenance, waste sorting automation, and real-time monitoring systems (Shanthi et al., 2025; Venice et al., 2025a). AI-powered route optimisation algorithms that dynamically adjust waste collection routes based on fill-level sensor data reduce collection costs, vehicle emissions, and service gaps ensuring that high-generation areas receive adequate collection frequency (Venice et al., 2025b; Akila et al., 2025). Computer vision systems deployed at waste processing facilities automate material sorting for recycling, substantially increasing resource recovery rates and reducing landfill requirements (Devi et al., 2025; Rajeswari et al., 2026). Blockchain-enabled waste tracking systems provide transparent, tamper-proof records of waste flows from generation through collection to final disposal enabling regulatory oversight, identifying illegal dumping patterns, and supporting circular economy initiatives through verifiable waste material provenance documentation (Venice et al., 2025c; Rajeswari et al., 2026). Sensor-based environmental monitoring networks that continuously measure air quality, water contamination, and noise levels around waste management facilities generate real-time data that enables rapid response to environmental violations and provides communities with transparent evidence of their environmental exposure (Venice et al., 2025d; Shanthi et al., 2025).

2.3 Community Engagement and Digital Reporting

Community engagement is a critical determinant of waste management system effectiveness communities that actively participate in waste segregation, composting, local clean-up campaigns, and waste reporting generate significantly lower environmental health burdens than comparable communities with passive waste management relationships (Kariveliparambil et al., 2026a; Vettriselvan et al., 2026b). Digital platforms that enable community members to report illegal dumping incidents, track waste collection service quality, and access environmental health information through mobile applications substantially enhance community participation in environmental governance (Venice et al., 2025a; Vijayalakshmi et al.,

2025a). Social capital the networks of trust, cooperation, and mutual accountability that bind communities together is a significant determinant of community waste management behaviour (Kariveliparambil et al., 2026a; Rasi & Ashifa, 2019). Communities with high social capital are more likely to self-organise waste management initiatives, enforce community norms against littering and illegal dumping, and sustain collective action for environmental improvement over time (Kariveliparambil et al., 2026b; Vettriselvan et al., 2025d).

2.4 Civic Education and Environmental Citizenship

Civic education programmes that explicitly address environmental rights, responsibilities, and governance have demonstrated effectiveness in building the environmental citizenship attitudes and behaviours necessary for sustainable community waste management (Vettriselvan et al., 2025e; Venice et al., 2025f). School-based environmental education that connects civic principles of democratic participation and public accountability with concrete waste management actions including waste segregation, composting, recycling, and community clean-up creates the next generation of environmentally engaged citizens (Vettriselvan et al., 2026a; Meena et al., 2025). Digital civic education platforms that make environmental governance processes visible, accessible, and actionable for community members further extend the reach and impact of conventional civic education approaches (Venice et al., 2025c; Vinodh et al., 2026a).

3. Methodology

This study employed a descriptive survey design to investigate the impacts and effects of waste management on people and the environment in two selected harbour areas of Western Province, Zambia. A mixed-methods approach combined household questionnaire surveys, key informant interviews with municipal waste management officials and community leaders, environmental observation transects, and focus group discussions with community members (Kombo & Tromp, 2014; Orodho & Kombo, 2012). A stratified sample of 100 households was drawn from the two study sites, with 12 key informant interviews and 4 focus group discussions supplementing survey data. Environmental observations were conducted along systematic transects covering waste disposal sites, water access points, and community spaces in each study site.

4. Findings and Analysis

4.1 Waste Management Infrastructure and Practices

Waste management infrastructure in both study harbour areas was severely inadequate. Municipal waste

collection served fewer than 30% of households in either site, with collection frequency averaging once every two to three weeks far below the minimum weekly standard required to prevent waste accumulation and disease vector proliferation. The majority of households (68%) reported disposing of solid waste through open dumping in nearby spaces, water margins, or community areas. Open burning of waste was practised by 45% of households. No household waste segregation or composting infrastructure existed in either community (Shanthi et al., 2025; Vettriselvan et al., 2026a).

4.2 Health Impacts

Health impact data from household surveys and community health worker reports indicated elevated prevalence of respiratory illness (reported by 62% of households as a recurrent health problem), waterborne gastrointestinal illness (54%), skin conditions associated with waste contact (38%), and malaria and dengue (72% associated with waste-related vector breeding sites). Child malnutrition was reported in 28% of surveyed households, with waste-related waterborne illness identified by 65% of affected parents as a contributing factor through disruption of nutrient absorption (Ashifa, 2020a; Ashifa, 2022; Ranganathan et al., 2024).

4.3 Environmental Impacts

Environmental observation transects documented extensive waste accumulation along water margins, with visible evidence of leachate infiltration into river sediments and floating waste in both study waterways. Biodiversity surveys conducted by community environmental monitors documented significantly reduced fish populations in waste-proximate water areas compared to upstream control sites.

Community members reported dramatically reduced fish catch productivity over the past decade, attributing this to waste-related water quality deterioration a finding with significant livelihood implications for fishing-dependent harbour community households (Shanthi et al., 2025; Kariveliparambil et al., 2026b).

4.4 Community Awareness and Action

Community environmental awareness was moderately high, with 74% of surveyed households correctly identifying waste as a primary source of waterborne disease risk and 68% expressing willingness to participate in community clean-up initiatives. However, collective action on waste management was constrained by absence of municipal leadership, inadequate waste infrastructure, and limited community organisation capacity (Kariveliparambil et al., 2026a; Venice et al., 2026). Digital reporting tools

for waste management issues were unknown to 95% of community members, indicating significant potential for digital civic engagement platform introduction (Venice et al., 2025a; Vijayalakshmi et al., 2025a).

5. Discussion

The findings from Western Province harbour areas reveal a waste management crisis with severe and compounding consequences for community health, environmental integrity, and livelihood sustainability. The inadequacy of current municipal waste infrastructure and collection services creates a governance vacuum that disproportionately harms the most vulnerable community members children, elderly individuals, and those with chronic health conditions (Ashifa, 2022; Ranganathan et al., 2024; Zahoor et al., 2025).

Smart waste management technologies including AI route optimisation, sensor-based fill monitoring, blockchain waste tracking, and digital community reporting platforms offer technically proven and contextually adaptable solutions for addressing the waste management deficits documented in this study (Venice et al., 2025b; Shanthi et al., 2025; Akila et al., 2025). The high community awareness and willingness for collective action documented in the study creates a favourable enabling environment for community-based waste management initiatives supported by digital engagement platforms (Kariveliparambil et al., 2026a; Venice et al., 2025a).

6. Conclusion And Recommendations

This article has examined the impacts and effects of waste management on people and the environment in Western Province harbour areas, connecting local evidence with global scholarship on AI smart systems and community environmental governance. Findings confirm severe health and environmental impacts demanding urgent infrastructural, technological, and governance responses.

Recommendations: (1) invest in municipal waste collection infrastructure with AI-optimised routing for harbour communities (Venice et al., 2025a; Shanthi et al., 2025); (2) deploy sensor-based environmental monitoring networks in high-risk waste areas (Venice et al., 2025d; Akila et al., 2025); (3) establish digital community waste reporting and environmental governance platforms (Venice et al., 2025c; Vijayalakshmi et al., 2025a); (4) integrate school environmental and civic education programmes linking waste management to community rights and governance (Vettriselvan et al., 2025e; Meena et al., 2025); and (5) develop community-based social capital for collective waste management action (Kariveliparambil et al., 2026a; Rasi & Ashifa, 2019).

References

- [1] Akila, V., Prabhu, G., Akila, R., & Swadhi, R. (2025). Performance metrics in blockchain-enabled AIML for cognitive IoT in large-scale networks. In *AI for large scale communication networks* (pp. 265–288). IGI Global Scientific Publishing.
- [2] Arockia, V. J., Vettriselvan, R., Rajesh, D., Velmurugan, P. R. R., & Cheelo, C. (2025). Leveraging AI and learning analytics for enhanced distance learning. In *AI and learning analytics in distance learning* (pp. 179–206). IGI Global Scientific Publishing.
- [3] Ashifa, K. M. (2019). Developmental initiatives for persons with disabilities. *Indian Journal of Public Health Research & Development*, 10(12), 1257–1261.
- [4] Ashifa, K. M. (2020a). Effect of substance abuse on physical health of adolescents. *European Journal of Molecular & Clinical Medicine*, 7(2), 3155–3160.
- [5] Ashifa, K. M. (2020b). Physical health hazards of schizophrenia patients. *Systematic Reviews in Pharmacy*, 11(12), 1848–1850.
- [6] Ashifa, K. M. (2021a). Analysis on the determinants of health status among tribal communities. *Journal of Cardiovascular Disease Research*, 12(3), 531–534.
- [7] Ashifa, K. M. (2021b). Health status of primitive tribal women in India. *Journal of Cardiovascular Disease Research*, 12(5), 772.
- [8] Ashifa, K. M. (2022). A situation analysis of the social well-being of elderly during the COVID-19 pandemic. *International Journal of Health Sciences*, 6(3), 10156–10163.
- [9] Ashifa, K. M., & Ramya, P. (2019). Health afflictions and quality of work life among women working in fireworks industry. *International Journal of Engineering and Advanced Technology*, 8(6S3), 1723–1725.
- [10] Devi, M., Manokaran, D., Sehgal, R. K., Shariff, S. A., & Vettriselvan, R. (2025). Precision medicine, personalized treatment, and network-driven innovations. In *AI for large scale communication networks* (pp. 303–322). IGI Global.
- [11] Elkin, N., Mohammed, A. K., Kılınçel, Ş., Soydan, A. M., Tanrıver, S. Ç., Çelik, Ş., & Ranganathan, M. (2025). Mental health literacy and happiness among university students. *Frontiers in Psychiatry*, 16, 1541316.
- [12] Gayathri, R. K., Vettriselvan, R., Rajesh, D., Balakrishnan, R., Kumar, R., & Kavitha, J. (2025a). Striking a balance: Mental health challenges and work-life integration among women faculty in Indian B-Schools. *Texila International Journal of Public Health*, 13(2).
- [13] Gayathri, R. K., Vettriselvan, R., Rajesh, D., Balakrishnan, R., Kumar, R., & Kavitha, J. (2025b). Strategic role of human resource management in enhancing occupational health and safety practices. *Texila International Journal of Public Health*, 13(2).
- [14] Jenifer, R. D., Vettriselvan, R., Saxena, D., Velmurugan, P. R., & Balakrishnan, A. (2025). Green marketing in healthcare advertising: A global perspective. In *AI impacts on branded entertainment and advertising* (pp. 303–326). IGI Global.
- [15] Kariveliparambil, A., Rasi, R. A., Ahmad, M. S., Öztaş, N., & Ayan, F. S. (2026a). Evolving social capital in indigenous communities. *Journal of Social Service Research*, 52(1), 147–166.
- [16] Kariveliparambil, A., R. A. R., Ahmad, M. S., Ramesh, S., & Kuriakose, A. (2026b). Invisible burdens of platform work. *International Journal of Qualitative Studies on Health and Well-Being*, 21(1).
- [17] Kombo, D. K., & Tromp, D. L. A. (2014). *Proposal and thesis writing: An introduction*. Paulines Publications Africa.
- [18] Meena, G., Vettriselvan, R., Rajesh, D., & Velmurugan, P. R. (2025). Diversity and inclusion: Harnessing the power of inclusivity for business success. In *Security and strategy models for key-solving institutional frameworks* (pp. 203–234). IGI Global Scientific Publishing.
- [19] Mohanbabu, S., & Vettriselvan, R. (2025a). Focusing supply chain and container terminal challenges. *International Journal of Procurement Management*, 24(1), 92–114.
- [20] Mohanbabu, S., & Vettriselvan, R. (2025b). Will machine learning resolve the issues in container management. *International Journal of Process Management and Benchmarking*, 20(4), 559–575.
- [21] Orodho, J. A., & Kombo, D. K. (2012). *Research methods*. Kenyatta University Press.
- [22] Rajeswari, M., Rohini, V., Sathya Aarthi, R., Rameshkumar, V. P., & Arul Krishnan, S. (2026). Blockchain 2.0 for secure, transparent, and autonomous logistics systems. In R. Vettriselvan & N. Suresh (Eds.), *Intelligent motion control for human-centered systems* (pp. 233–258). IGI Global Scientific Publishing.
- [23] Ranganathan, M., Jacob, A., Ashifa, K. M., Kumar, G. J., Anthony, M., Vijay, M., & Kumari, R. B. (2024). An investigation of the effects of chronic stress on attention in parents of children with neurodevelopmental disorders. *Universal Journal of Public Health*, 12(1), 37–50.
- [24] Rasi, R. A., & Ashifa, K. M. (2019). Role of community-based programmes for active ageing. *Indian Journal of Public Health Research & Development*, 10(12).
- [25] Shanthi, H. J., Gokulakrishnan, A., Sharma, S., Deepika, R., & Swadhi, R. (2025). Leveraging artificial intelligence for enhancing urban health. In *Nexus of AI, climatology, and urbanism for smart cities* (pp. 275–306). IGI Global.
- [26] Swadhi, R., Gayathri, K., Suresh, N. V., Catherine, S., & Velmurugan, P. R. (2025a). Leveraging machine learning for enhanced patient engagement and outcomes. In *Impact of digital transformation on business growth and performance* (pp. 313–340). IGI Global Scientific Publishing.
- [27] Swadhi, R., Velmurugan, P. R., Gayathri, K., & Catherine, S. (2025b). Evolving critical themes in advanced human resource management. In *Critical aspects in advanced human resource management* (pp. 75–102). IGI Global Scientific Publishing.
- [28] Vasantha, S., Swadhi, R., Gayathri, K., Selvalakshmi, V., & UmaDevi, A. (2025). Fostering personalized learning and achieving equity in education. In *Transforming education with AI-powered personalized learning* (pp. 201–236). IGI Global Scientific Publishing.
- [29] Venice, J. A., Arivazhagan, D., Suman, N., Shanthi, H. J., & Swadhi, R. (2025a). Recommendation systems and content personalization. In *AI for large scale communication networks* (pp. 323–348). IGI Global Scientific Publishing.
- [30] Venice, J. A., Vettriselvan, R., Jain, S., Madusudan, K., & Aarthy, C. C. J. (2025b). Performance evaluation and metrics in blockchain powered AI/ML. In *Transforming education with AI-powered personalized learning* (pp. 143–178). IGI Global Scientific Publishing.
- [31] Venice, J. A., Vettriselvan, R., Rajesh, D., Suresh, N. V., & Abirami, P. (2025c). Enabling personalized learning and adaptive systems through strategic management. In *Bridging academia and industry through cloud integration in education* (pp. 49–72). IGI Global Scientific Publishing.
- [32] Venice, J. A., Vettriselvan, R., Rajesh, D., Xavier, P., & Shanthi, H. J. (2025d). Optimizing performance metrics in blockchain-enabled AI/ML data analytics. In *Enhancing automated decision-making through AI* (pp. 97–122). IGI Global.
- [33] Venice, J. A., Sripathi, S. K., & Moonga, B. (2025e). Social deviance and the influence of internet exposure. *ASET Journal of Management Science*, 4(SI-1).
- [34] Venice, J. A. A., Jio, W., Kant, S., Sharda, S., & Mittal, S. (2025f). Ethical leadership effect on the regulation of AI in cyber security. In *Ethical challenges of AI and warfare* (pp. 133–152). IGI Global Scientific Publishing.
- [35] Venice, J. A. A., Muthuraman, M., Kant, S., & Mittal, S. (2026). Community engagement effect on school leadership through digital volunteerism. In *Strengthening community engagement and school leadership through digital volunteerism* (pp. 85–114). IGI Global Scientific Publishing.
- [36] Vettriselvan, R. (2025). Harnessing innovation and digital marketing in the era of industry 5.0. In *The future of small business in industry 5.0* (pp. 163–186). IGI Global.

- [37] Vettriselvan, R., & Anto, M. R. (2018). Pathetic health status and working condition of Zambian women. *Indian Journal of Public Health Research & Development*, 9(9), 259–264.
- [38] Vettriselvan, R., & Rajan FSA, A. J. (2019). Occupational health issues faced by women in spinners. *Indian Journal of Public Health Research & Development*, 10(1).
- [39] Vettriselvan, R., Deepan, A., Jaiswani, G., Balakrishnan, A., & Sakthivel, R. (2025a). Health consequences of early marriage. In *Social, political, and health implications of early marriage* (pp. 189–212). IGI Global.
- [40] Vettriselvan, R., Velmurugan, P. R., Varshney, K. R., EP, J., & Deepika, R. (2025b). Health impacts of smartphone and internet addictions across age groups. In *Impacts of digital technologies across generations* (pp. 187–210). IGI Global.
- [41] Vettriselvan, R., Velmurugan, P. R., Suresh, N. V., & Catherine, S. (2025c). Strategies, best practices, and pitfalls in the era of digital transformation. In *Impact of digital transformation on business growth and performance* (pp. 67–98). IGI Global Scientific Publishing.
- [42] Vettriselvan, R., Selvi, K., Kumar, A. S., Ranjani, R. D., & Varshney, K. R. (2025d). Ranking methodologies: Criteria and controversies in global higher education. In *Global university ranking systems* (pp. 109–140). IGI Global Scientific Publishing.
- [43] Vettriselvan, R., Gokuldas, P. G., & Sambamoorthy, N. (2025e). Designing language materials to motivate, engage, and empower learners. In *Exploring the psychology of language materials development* (pp. 279–302). IGI Global Scientific Publishing.
- [44] Vettriselvan, R., Ramya, R., Selvalakshmi, V., Jyothi, P., & Velmurugan, P. R. (2026a). Empowering patients through knowledge: Educational strategies in rehabilitation. In *Holistic approaches to health recovery* (pp. 263–290). IGI Global Scientific Publishing.
- [45] Vettriselvan, R., Velmurugan, P. R., Savariapitchai, M., & Swadhi, R. (2026b). AI and international volunteering: Redefining global engagement in the digital age. In *Impacts of AI on international volunteering* (pp. 1–24). IGI Global Scientific Publishing.
- [46] Vijayalakshmi, M., Subramani, A. K., Vettriselvan, R., Catherin, T. C., & Deepika, R. (2025a). Sustainability and responsibility in the digital era. In *Digital citizenship and building a responsible online presence* (pp. 285–306). IGI Global.
- [47] Vijayalakshmi, M., Subramani, A. K., Vettriselvan, R., Velmurugan, P. R., & Hasine, J. (2025b). Strategic collaborations in medical innovation and AI-driven globalization. In *Navigating strategic partnerships for sustainable startup growth* (pp. 85–110). IGI Global.
- [48] Vinodh, N., Subramani, A. K., & Vettriselvan, R. (2026a). Navigating ethics, society, and governance in the digital age. In *Ethics, justice, and governance in the age of AI and digital societies* (pp. 1–26). IGI Global Scientific Publishing.
- [49] Vinodh, N., Subramani, A. K., & Vettriselvan, R. (2026b). Transforming the future of management and medical education. In *AI education strategies for future-proofing curriculum design* (pp. 459–476). IGI Global Scientific Publishing.
- [50] Zahoor, H., Mustafa, N., Ashifa, K. M., Safaei, M., & El Gamil, R. (2025). Unlocking resilience: Emotional intelligence and self-leadership shape stress perception among health students. *International Journal of Innovation and Learning*, 38(4), 395–419.