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From Crisis Response to Preventive Administration: A Policy Framework for Microbial Surveillance and Antimicrobial Resistance Management in Nigerian Urban Centres

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ABSTRACT

This comprehensive review synthesizes current scientific evidence to evaluate the critical public health threats emanating from urban microbial pollution in Nigeria and assesses the potential of microbial-based surveillance, remediation, and management solutions. Nigeria's rapid urbanization, characterized by overcrowded slums, inadequate sanitation, and overwhelmed waste management systems, has created pervasive reservoirs for pathogens and antimicrobial resistance (AMR) genes . This review analyzes the composition and health risks of microbial contaminants in key environmental matrices: wastewater canals harboring enteropathogens and non-tuberculous mycobacteria, bioaerosols emitted from waste sites and high-traffic public spaces containing resistant bacteria and fungi , and medical waste streams acting as vectors for AMR dissemination**.** It identifies that drivers such as the ease of over-the-counter antibiotic access, weak regulatory enforcement, and public knowledge gaps have escalated AMR into a present crisis, straining healthcare and increasing mortality. Crucially, the review advocates for a paradigm shift towards microbial-based intelligence systems, such as wastewater-based epidemiology (WBE), as a cornerstone for proactive public health management. WBE provides a cost-effective, community-wide surveillance tool for early outbreak detection and AMR tracking. We propose an integrated "One Health" policy framework that synergizes enhanced microbial surveillance, targeted infrastructure investment in sanitation and affordable housing, strict antimicrobial stewardship, and robust public education. By harnessing microbial data for decision-making and deploying microbiological solutions for environmental remediation, Nigerian urban public health administration can transition from reactive crisis management to sustainable, preventive, and data-driven health security.

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Microbial Surveillance, Wastewater-Based Epidemiology (WBE), Antimicrobial Resistance (AMR), Bioaerosols, One Health, Urban Public Health, Nigeria, Pathogen Detection, Sanitation, Public Health Policy

1. INTRODUCTION

Nigeria is in the throes of a profound epidemiological transition, driven by one of the most rapid urban population growth rates in the world (Adesola et al., 2024; Chukwu et al., 2024). This demographic surge, concentrated in sprawling megacities like Lagos, has vastly outstripped the development of essential infrastructure, creating a perfect storm for public health crises rooted in microbial contamination. The convergence of overcrowded slum housing, inadequate and often non-existent sewage systems, poorly managed solid and medical waste, and rampant pollution has transformed urban environments into vast reservoirs and transmission hubs for pathogenic microorganisms.

The consequences are a debilitating double burden of disease. Infectious diseases, facilitated by poor sanitation and overcrowding, remain rampant. Concurrently, the uncontrolled misuse of antibiotics in human and animal health has fueled an explosive rise in antimicrobial resistance (AMR), now declared a "present crisis" that threatens to render standard treatments ineffective and make routine medical procedures high-risk (Awulu et al., 2025; Ebekozien et al., 2025). This AMR crisis is amplified through environmental pathways, as resistant bacteria and genes are shed into wastewater, disseminated through improper medical waste disposal, and even carried by insect vectors like flies in hospital settings (Yusuf and Olaleye, 2025; Ineos Oxford Institute for Antimicrobial Research, 2025).

Traditional public health management in this context is predominantly reactive, relying on clinical case reports that emerge only after community transmission is widespread. This review posits that a sustainable future for Nigerian urban health requires a fundamental shift towards preventive, intelligence-driven strategies anchored in microbial science. It argues for the adoption of microbial-based solutions—not only as bioremediation tools but, more critically, as surveillance and diagnostic systems to understand the invisible microbial landscape of cities. By systematically monitoring pathogens and AMR markers in wastewater, air, and environmental samples, public health authorities can gain real-time, population-level insights to guide interventions. This document provides a comprehensive analysis of the scientific evidence for urban microbial pollution threats, critically evaluates the potential of microbial-based technologies for management, and proposes an integrated policy and implementation framework to harness this approach for sustainable public health in Nigeria's urban centers.

2. THE STATE OF EVIDENCE: MICROBIAL CONTAMINATION HOTSPOTS AND HEALTH IMPACTS

2.1. Wastewater and Surface Water: A Conduit for Enteropathogens and AMR

Urban waterways in Nigeria, often functioning as open sewers, represent a primary reservoir for pathogens. A landmark 2024 surveillance study of 40 wastewater canals across Lagos State provides stark evidence. The research detected a high prevalence of clinically critical bacteria, including *Escherichia coli* (28.5%), *Salmonella* spp. (16.3%), *Vibrio cholerae* (10.6%), and *Shigella* spp. (5.7%) (Adesola et al., 2024). Of grave concern was the finding of non-tuberculous mycobacteria (NTM), such as *Mycobacterium fortuitum* and *M. kansasii*, in 75% of the surveyed Local Government Areas. NTMs are environmentally resistant and can cause severe pulmonary diseases, particularly in immunocompromised individuals, and are notoriously difficult to treat (Adesola et al., 2024; Esther et al., 2025).

Perhaps most alarming is the role of these waterways in circulating antimicrobial resistance. The same study found that 87.5% of wastewater samples contained extended-spectrum beta-lactamase (ESBL) genes, with nearly half harboring multiple gene types (Adesola et al., 2024). This indicates that urban canals are not merely passive recipients of waste but active bioreactors where the genetic elements of resistance are exchanged and amplified, posing a direct threat to community health through potential exposure and contamination of the broader environment.

2.2. Airborne Threats: Bioaerosols from Waste and Public Spaces

The microbial threat is not confined to water; it becomes airborne through bioaerosols—airborne particles containing living organisms. Activities at solid waste processing facilities, such as loading, sorting, and composting, are significant emission sources. A study highlighted that such sites emit bioaerosols with average concentrations of 2,979 ± 544 CFU/m³ for bacteria and 2,288 ± 1,128 CFU/m³ for fungi (Odeyemi et al., 2024; Vishwakarma et al., 2025). Metagenomic analysis revealed genera including *Stenotrophomonas* and *Fusarium*, with dominant bacterial strains showing resistance to antibiotics like azithromycin and cefixime (Vishwakarma et al., 2025). Nearby residents and workers report higher incidences of respiratory, skin, and eye irritation, directly linking this exposure to health outcomes.

High-traffic public spaces are also contamination hubs. Research in motor parks and marketplaces in Southwestern Nigeria isolated pathogenic bioaerosols containing *Staphylococcus aureus*, *E. coli*, *Klebsiella* sp., and *Pseudomonas aeruginosa*, alongside fungi like *Aspergillus* and *Fusarium* (Odeyemi *et al.*, 2024). These environments, characterized by high human density and often poor waste management, facilitate the airborne transmission of microbes responsible for respiratory and gastrointestinal infections, creating an invisible health risk for the urban populace.

2.3. Medical Waste and Institutional Amplification of AMR

Healthcare facilities, intended to heal, can become epicenters for disseminating resistant microbes through inadequate waste management. A mixed-methods assessment of facilities in Lagos found critical systemic failures: only 61% proper segregation at source, storage times exceeding recommended limits by up to 5 times, and the mixing of antimicrobial-containing waste with general streams (Yusuf and Olaleye, 2025). Pharmaceutical waste, comprising 5-8% of the total, receives no specialized treatment capable of degrading active compounds, leading to environmental discharge.

This mismanagement creates multiple spillover pathways. Research has identified flies in Nigerian hospital wards as active vectors carrying multidrug-resistant bacteria. A study across eight hospitals found 40% of flies carried bacteria with ESBL genes, and 8% carried the *bla*NDM gene, which confers resistance to last-resort carbapenem antibiotics (Ineos Oxford Institute for Antimicrobial Research, 2025). These insects move freely between hospital wards, waste sites, and the community, physically transporting resistant pathogens and accelerating their spread in urban settings.

Wastewater canals in Lagos have been identified as a major contamination hotspot. A 2024 surveillance study found high levels of enteropathogens, including *E. coli*, *Salmonella* spp., and *V. cholerae*, as well as non-tuberculous mycobacteria (NTM) in most surveyed areas. The widespread presence of extended-spectrum beta-lactamase (ESBL) genes indicates these waterways are a significant route for community-wide antimicrobial resistance (AMR) exposure, posing risks of diarrheal diseases and pulmonary infections (Adesola et al., 2024).

Bioaerosols emitted from solid waste processing facilities present another critical health threat. Research on these sites identified airborne bacteria and fungi from genera like *Stenotrophomonas* and *Fusarium*, with dominant bacterial strains showing resistance to antibiotics such as azithromycin and cefixime. These contaminated aerosols are linked to respiratory infections, skin and eye irritation, and systemic fungal illnesses in exposed populations (Ebekozien et al., 2025; Vishwakarma et al., 2025).

Beyond formal waste sites, high-traffic public spaces like motor parks and marketplaces are also heavily contaminated. A 2024 assessment in southwestern Nigeria isolated pathogenic bioaerosols containing *Staphylococcus aureus*, *E. coli*, *Klebsiella* sp., *Pseudomonas aeruginosa*, and fungi like *Aspergillus*. These environments facilitate the airborne transmission of pathogens responsible for respiratory and gastrointestinal infections (Odeyemi *et al.*, 2024).

Finally, healthcare environments and their mismanaged waste create a unique danger zone. Research has identified flies in Nigerian hospital wards as active vectors carrying multidrug-resistant bacteria, with some carrying genes (e.g., *bla*NDM) that confer resistance to last-resort antibiotics. This, combined with systemic failures in medical waste segregation and treatment, turns hospitals into epicenters for disseminating pan-resistant "superbugs," leading to hospital-acquired infections (Ineos Oxford Institute for Antimicrobial Research, 2025; Yusuf and Olaleye, 2025).

3. SYSTEMIC DRIVERS: THE UNDERLYING CAUSES OF THE CRISIS

3.1. The Antimicrobial Resistance Catalyst

The proliferation of resistant microbes in the environment is directly fueled by profound systemic failures in antimicrobial stewardship. A 2025 expert prioritization study identified "ease of access to over-the-counter antimicrobials" and "lack of awareness of AMR" as the top challenges in both human and animal health sectors in Nigeria (Chukwu et al., 2025). This is underpinned by weak regulatory enforcement, allowing antibiotics to be sold freely in markets, by street vendors, and in pharmacies without prescription, normalizing self-medication and inappropriate use.

The clinical and economic impacts are severe. A comprehensive 2025 review found high AMR rates, including 67.8% methicillin-resistant *Staphylococcus aureus* (MRSA) in hospitals. The economic burden is staggering, with AMR costing an estimated 2.4% of Nigeria's GDP, and treating a resistant infection costs 287% more than a susceptible one (Ebekozien et al., 2025). This cycle is perpetuated by limited diagnostic capacity—only 23.4% of secondary facilities have microbiology labs—leading to empirical, often incorrect, antibiotic prescribing (Ebekozien et al., 2025).

3.2. Urban Planning and Infrastructure Deficits

Rapid, unplanned urbanization is a primary driver of microbial exposure. Population growth exacerbates overcrowding, straining sanitation systems and creating ideal conditions for disease transmission (Adesola et al., 2024). Affordable housing is critically scarce, forcing millions into slums characterized by poor ventilation, inadequate sanitation, and a lack of clean water, which directly promotes the spread of infectious diseases (Ebekozien et al., 2025).

The infrastructure to manage the waste generated by these dense populations is utterly inadequate. Open dumping and poorly managed processing facilities, as documented in the bioaerosol studies, turn waste sites from disposal problems into active public health hazards, exposing workers and nearby communities to pathogenic clouds (Ebekozien et al., 2025). This confluence of demographic pressure and infrastructural failure creates the physical landscape in which microbial threats thrive.

4. A FRAMEWORK FOR SUSTAINABLE MICROBIAL-BASED PUBLIC HEALTH MANAGEMENT

To transition from crisis response to sustainable management, Nigeria must adopt an integrated, "One Health" framework that leverages microbial intelligence for proactive decision-making. This framework rests on four pillars:

Pillar 1: Deploy Microbial Surveillance Intelligence Systems

Implement National Wastewater-Based Epidemiology (WBE): Establish a sentinel network to routinely monitor wastewater for priority pathogens (*Salmonella*, *V. cholerae*, NTMs) and AMR markers (ESBL, carbapenemase genes). This provides real-time, population-level data for early outbreak warning and AMR trend tracking, bypassing the biases of clinical reporting (Adesola et al., 2024). Expand Environmental Bioaerosol Monitoring: Routinely assess bioaerosol composition and load at high-risk sites (major waste processing plants, densely populated markets, hospital perimeters) to quantify exposure risks and evaluate the effectiveness of control measures (Vishwakarma et al., 2025; Odeyemi *et al.*, 2024).

Pillar 2: Strengthen Core Urban Infrastructure and Regulation

Invest in Sanitation and Affordable Housing: Direct policy and funding towards closing the sanitation gap and developing affordable housing with integrated water and sanitation services, as foundational measures to reduce pathogen reservoirs in communities (Adesola et al., 2024).

Enforce Medical Waste and Pharmaceutical Regulations: Strengthen and enforce regulations for medical waste segregation, storage, and treatment with technologies effective against AMR (e.g., advanced oxidation). Simultaneously, crack down on the illegal over-the-counter sale of antibiotics through robust enforcement of NAFDAC and PCN mandates (Yusuf and Olaleye, 2025; Vishwakarma et al., 2025).

Pillar 3: Implement Targeted Microbial Control Interventions

Apply Bioengineering Solutions: Support research and pilot projects for using engineered microbial consortia or enzymatic treatments in wastewater treatment to enhance the degradation of pharmaceutical residues and reduce the biological load of AMR genes before environmental discharge.

Mandate Infection Prevention in Healthcare: Enforce stringent infection prevention and control (IPC) protocols, including effective insect vector control (e.g., insect screens, air curtains) in hospitals to break the vector-borne transmission of AMR identified in the fly studies (Ineos Oxford Institute for Antimicrobial Research, 2025).

Pillar 4: Launch Coordinated "One Health" Education and Stewardship

Execute Nationwide Public Awareness Campaigns: Launch sustained, multi-lingual campaigns to educate the public on the dangers of AMR and the proper use of antibiotics, targeting misconceptions that drive self-medication.
Establish Antimicrobial Stewardship Programs (ASPs): Mandate and resource ASPs in all tertiary and secondary healthcare facilities, and extend stewardship principles to the agricultural and veterinary sectors to curb non-human antibiotic misuse.

CONCLUSION

Nigerian cities face an acute public health crisis fueled by environmental microbial pollution and rampant antibiotic misuse. The persistent circulation of dangerous pathogens and resistance genes in water, air, and waste is a direct driver of illness and economic strain. This urgent situation demands a fundamental shift from reactive treatment to a proactive strategy of diagnosing and healing the urban environment. A sustainable solution lies in leveraging the science of microbes themselves, turning them from a threat into a tool for intelligence and control to build a resilient public health system.

RECOMMENDATIONS

To achieve this, coordinated action is essential. The federal government must establish a National Wastewater-Based Epidemiology Program to transform sewage into a real-time health data stream. State authorities must prioritize core sanitation infrastructure and enforce air quality standards at waste sites. Regulatory bodies must decisively end the illegal over-the-counter sale of antibiotics. Simultaneously, researchers and partners must develop affordable microbial treatment technologies and build local scientific capacity to sustain this new, data-driven approach to public health management.

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