International Journal of Emerging Research in Science, Engineering, and Management
Vol. 1, Issue 2, pp.26-31, August 2025.
www.ijersem.com

Comparative Study of Antimicrobial Resistance in Urban vs Rural Areas

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Abstract: Antimicrobial resistance (AMR) is a growing global health concern, driven by complex interactions across clinical, environmental, and socioeconomic domains. While much research has focused on AMR prevalence in urban healthcare settings, rural environments—often lacking structured surveillance—are emerging as critical reservoirs of resistance genes. This paper presents a comparative study of AMR patterns in urban versus rural areas, synthesizing recent research on clinical isolates, environmental samples, livestock-associated resistance, and socio-behavioral drivers. The analysis reveals higher detection of extended-spectrum beta-lactamase (ESBL) and carbapenem-resistant organisms in urban hospitals, while rural regions show elevated levels of environmental and zoonotic transmission of resistant bacteria, often linked to agricultural runoff, poor waste management, and informal antibiotic use. Socioeconomic disparities further exacerbate resistance by varying hygiene, healthcare access, and awareness. The study underscores the importance of adopting a One Health approach and improving AMR surveillance and stewardship strategies tailored to the specific risks of both urban and rural contexts.

Keywords: Antimicrobial resistance, One Health, Rural health, Socioeconomic factors, Urban-rural comparison.

1 Introduction

Antimicrobial resistance (AMR) poses a serious threat to public health worldwide, undermining decades of progress in treating infectious diseases. As pathogens evolve to resist commonly used antibiotics, infections become harder to treat, leading to increased morbidity, mortality, and healthcare costs. The World Health Organization (WHO) has declared AMR as one of the top 10 global public health threats [1]. Traditionally, the focus of AMR surveillance and research has been centered on urban healthcare settings, where the density of clinical facilities and antibiotic usage is higher. However, emerging studies highlight that rural environments are also significant contributors to the spread of AMR, particularly through agricultural practices, poor waste disposal, and untreated environmental discharges [2][3]. The contrast between urban and rural drivers of AMR is stark—urban areas tend to show high clinical resistance due to antibiotic overuse and hospital-acquired infections, while rural areas often exhibit resistance linked to environmental contamination, zoonotic transmission, and unregulated antibiotic consumption in livestock [4][5].

Recent investigations have revealed widespread resistance to critical antibiotics, including carbapenems, colistin, and third-generation cephalosporins, in both urban hospitals and rural communities [6][7]. Environmental studies show that rivers in rural regions serve as reservoirs for antibiotic-resistant genes (ARGs), often driven by hydrological and land-use factors [2][3]. In contrast, urban areas experience elevated risk due to healthcare-associated transmission and poor antimicrobial stewardship in overcrowded facilities [6][8]. The urban–rural divide also extends to socioeconomic dimensions. Factors such as income levels, education, healthcare infrastructure, sanitation, and hygiene practices significantly influence AMR dynamics in both settings [1][9].

Additionally, surveillance and diagnostic capacities differ widely, resulting in knowledge gaps and delayed responses, particularly in low- and middle-income countries [6][5]. This paper aims to provide a comparative analysis of AMR in urban and rural areas by synthesizing findings from environmental, clinical, and socioeconomic studies. The goal is to identify key differences, overlaps, and drivers of resistance patterns across these settings, and to propose context-specific strategies for AMR surveillance, control, and policy-making within a One Health framework.

2 Literature Review

Antimicrobial resistance (AMR) is a multifactorial issue shaped by clinical, environmental, agricultural, and social drivers. The contrast between urban and rural AMR patterns has gained increased research attention in recent years, particularly through One Health studies that integrate human, animal, and environmental health data.

2.1 Environmental Reservoirs and Riverine AMR in Rural Settings

Robins et al. [2] compared two rural river catchments in Northern England using quantitative microbial profiling and found significantly higher ARG abundance and diversity in the Eden River compared to the Coquet.

Hydrological factors and agricultural runoff were identified as major contributors to environmental AMR, underlining the influence of geographical and land-use characteristics in rural AMR dissemination. Similarly, Naznine et al. [3] emphasized rivers as key reservoirs for AMR transmission due to contamination from hospital, municipal, and industrial waste. These findings show that rural water bodies—though often distant from hospitals—can harbor clinically relevant resistance genes.

2.2 Agricultural Antibiotic Use and AMR in Rural Livestock

Mbatidde et al. [4] investigated poultry farms in Uganda and reported the widespread presence of colistin- and cefotaxime-resistant *E. coli* in both semi-intensive and free-range systems. Even in the absence of direct correlations between antibiotic use and resistance, the study found multidrug-resistant strains in rural settings, suggesting environmental or indirect drivers. Alam et al. [10] further illustrated the risks of AMR in Bangladesh's small-scale poultry farms, where poor hygiene and waste-disposal practices increased human exposure to resistant bacteria through soil and water pathways.

2.3 Clinical Resistance in Urban Healthcare Settings

Urban areas often report a higher prevalence of clinically significant AMR due to hospital-acquired infections and frequent antibiotic use. Gach et al. [6] conducted a systematic review in Indonesia and noted high levels of carbapenem resistance in *Klebsiella pneumoniae* and *Acinetobacter baumannii*, especially in hospital samples. Similarly, ALjohni et al. [5] reported increasing resistance among E. coli strains producing extended-spectrum beta-lactamases (ESBLs) and carbapenemases, highlighting the public health burden in urban healthcare systems. Seni et al. [11] also reported that referral hospitals had significantly higher resistance rates than lower-tier healthcare facilities in Tanzania.

2.4 One Health and Cross-Sectoral Genomic Studies

Calland et al. [7] implemented a One Health genomic approach in Ghana, comparing *Klebsiella* isolates from human, animal, and environmental samples. The results revealed that hospital strains had a higher prevalence of ESBL genes, while environmental samples from rural sources were less resistant. This reinforced the concept that clinical settings are primary hotspots for critical resistance traits, although gene flow across domains remains a concern. These insights support targeted interventions at healthcare centers while also recognizing environmental contributions.

2.5 Socioeconomic and Policy Drivers

AMR is not only a biological issue but also a social one. Ljungqvist et al. [1] performed an umbrella review to map socioeconomic drivers of AMR, highlighting key variables such as urbanicity, healthcare access, hygiene, and poverty. Differences in public awareness, antibiotic availability, and sanitation services between rural and urban populations influence the development and transmission of resistance. Verma et al. [8] evaluated an antimicrobial stewardship programme in an urban trauma center in North India, demonstrating how policy and surveillance gaps can be addressed through targeted hospital interventions.

2.6 Predictive Tools and Machine Learning Applications

Wu et al. [9] introduced machine learning techniques to estimate relative AMR risk in aquatic environments based on land-use and environmental parameters. Among the algorithms tested, random forests provided the most accurate predictions. These models offer practical value for predicting AMR hotspots in both rural and urban water systems, where routine monitoring may be limited. The reviewed literature clearly shows that AMR patterns are context-dependent: urban areas are dominated by clinical and nosocomial resistance, while rural settings exhibit resistance arising from environmental and agricultural pathways. These findings collectively support a multidimensional, One Health perspective to understand and mitigate AMR risks [12].

3 METHODOLOGY

This study adopts a comparative, review-based methodology to synthesize and analyze patterns of antimicrobial resistance (AMR) across urban and rural contexts, using a One Health framework. Rather than conducting primary experiments or data collection, this paper systematically examines existing peer-reviewed studies and datasets across environmental, clinical, agricultural, and socioeconomic domains to identify trends, contrasts, and key drivers of AMR.

3.1 Selection of Studies

Ten recent and high-quality studies were selected based on the following criteria:

- Peer-reviewed journal articles published between 2019 and 2025.
- Research focusing on AMR in environmental (e.g., river systems), clinical (e.g., hospitals), agricultural (e.g., poultry farms), or community settings.

- Studies offering comparative insights into urban and rural dynamics of AMR or offering data that could be interpreted through this lens.
- Inclusion of data from both high-income and low- and middle-income countries to account for geographic and socioeconomic variability.

The selected studies were analyzed for:

- Prevalence and types of antimicrobial-resistant organisms or genes.
- Environmental or clinical sources of AMR.
- Socioeconomic or behavioral drivers of resistance.
- Surveillance, diagnostic, or stewardship practices.

3.2 Analytical Framework

The comparative analysis was conducted under four thematic axes:

- Clinical AMR Prevalence: Resistance patterns in healthcare settings, stratified by level of care (primary vs tertiary) and location (urban vs rural).
- Environmental and Agricultural Sources: Role of rivers, poultry farming, and waste disposal in rural AMR dynamics.
- Socioeconomic and Behavioral Influences: Factors such as hygiene practices, antibiotic knowledge, and healthcare accessibility.
- Surveillance and Policy Implementation: Differences in AMR monitoring and response mechanisms between urban and rural areas.

Data extracted from each study were narratively synthesized and grouped to highlight urban–rural contrasts in AMR presence, drivers, and outcomes.

3.3 Limitations

As a review-based study, this work is subject to certain limitations. The availability of uniform data across urban and rural contexts is limited in some regions, particularly in low-income settings. Moreover, variations in study design, sampling strategies, and laboratory methodologies across the referenced literature may affect direct comparability. No original laboratory testing or field sampling was conducted for this study.

4 COMPARATIVE ANALYSIS: URBAN VS RURAL AMR PATTERNS

The burden of antimicrobial resistance (AMR) manifests differently across urban and rural areas due to distinct environmental exposures, antibiotic usage patterns, healthcare infrastructure, and socioeconomic dynamics. Based on the literature reviewed, this section outlines comparative trends across key domains contributing to AMR emergence and spread.

4.1 Clinical AMR Prevalence

Urban healthcare systems, particularly tertiary hospitals, tend to report a higher incidence of drug-resistant infections due to frequent use of broad-spectrum antibiotics and poor antimicrobial stewardship. Gach et al. [6] observed alarming levels of resistance in *Klebsiella pneumoniae* and *Acinetobacter baumannii* in Indonesian hospitals, with increasing trends over time. Similarly, ALjohni et al. [5] highlighted the growing threat of extended-spectrum beta-lactamase (ESBL) and carbapenem-resistant *E. coli* in clinical environments. In rural healthcare settings, resistance is often underreported due to limited diagnostic capacity and surveillance. However, studies such as that by Seni et al. [11] show that even lower-tier rural healthcare facilities in Tanzania report significant resistance, with third-generation cephalosporin-resistant strains becoming increasingly common. Although overall clinical exposure may be lower in rural areas, inappropriate prescribing practices and delayed diagnoses contribute to the development and transmission of resistance.

4.2 Environmental and Agricultural Sources of Resistance

Rural areas, despite lower clinical antibiotic use, often serve as reservoirs of resistance due to environmental contamination. Robins et al. [2] demonstrated significantly higher ARG abundance in rivers with greater agricultural runoff and hydrological connectivity. Agricultural practices, including the unregulated use of antibiotics in poultry and livestock, contribute to reservoirs of resistance in rural soils and water bodies [4][10]. Environmental studies, such as those by Naznine et al. [5], have emphasized that rivers and open drains serve as conduits for horizontal gene transfer, enabling the spread of resistance genes across microbial populations. Waste disposal from farms and the entry of animal waste into aquatic systems amplify these risks.

In contrast, while urban rivers also contain ARGs, these are more commonly linked to sewage discharges and hospital effluents rather than agricultural inputs.

4.3 Socioeconomic and Behavioral Factors

Socioeconomic disparities significantly shape AMR risks. Urban populations may have better access to healthcare and public awareness campaigns but are also exposed to high-risk environments such as hospitals and crowded residential settings. Rural populations, on the other hand, often engage in self-medication, use leftover antibiotics, or purchase antimicrobials without prescriptions due to limited healthcare access. Ljungqvist et al. [1] mapped a range of socioeconomic drivers, including urbanicity, sanitation, education, and income. Their review revealed that low educational attainment and poor hygiene practices—common in rural areas—are associated with higher risk of AMR development. Alam et al. [9] further highlighted unsafe handling and waste-disposal practices in rural poultry farming, thereby increasing human exposure to resistant organisms.

4.4 Surveillance, Policy, and Stewardship Gaps

Urban areas generally benefit from centralized surveillance systems, antimicrobial stewardship programmes, and regulatory mechanisms. Verma et al. [8] showed significant improvement in antimicrobial prescription patterns following the implementation of a hospital-based stewardship programme in North India. However, the reach of such initiatives is often limited to urban tertiary centers. Rural areas suffer from fragmented or non-existent surveillance. Calland et al. [7] found that although resistance genes were present in rural environmental samples in Ghana, critical clinical resistance genes were largely restricted to hospital samples. This indicates both the need for improved diagnostics in rural clinics and the urgency of environmental interventions.

Predictive models, such as those developed by Wu et al. [9], offer promise for both settings by identifying high-risk zones for AMR based on environmental and land-use features. These tools can guide surveillance efforts where conventional infrastructure is lacking. This comparative analysis underscores the complexity of AMR dynamics. While urban areas bear the brunt of clinically relevant resistance, rural environments remain persistent, often overlooked sources of environmental and zoonotic AMR. Effective intervention requires parallel strategies tailored to the unique risks of both urban and rural ecosystems.

5 DISCUSSION

The comparative synthesis of the literature reveals that antimicrobial resistance (AMR) is shaped by diverse factors, with urban and rural settings exhibiting distinct yet interconnected risk profiles. While clinical settings in urban areas are primary sites for multidrug-resistant infections, rural areas contribute substantially through environmental and agricultural pathways, often in the absence of structured surveillance or regulatory frameworks. In urban settings, high patient turnover in hospitals, frequent antibiotic use, and inadequate stewardship policies drive the emergence and spread of resistant pathogens. Studies consistently show elevated resistance to carbapenems, colistin, and third-generation cephalosporins in hospital-acquired infections [6][5]. However, these environments also offer opportunities for targeted interventions, such as antimicrobial stewardship programs [8], which have proven effective in improving prescription patterns and reducing resistance rates.

Rural areas, in contrast, are characterized by decentralized healthcare systems, limited diagnostic capabilities, and widespread informal antibiotic use. Environmental vectors—such as contaminated rivers and agricultural runoff—play a dominant role in the propagation of AMR. As shown in studies from England, Uganda, and Bangladesh [2][4][10], rural rivers and poultry farms often contain high levels of ARGs and resistant bacteria, suggesting long-term environmental reservoirs of AMR. Another major distinction lies in behavioral and socioeconomic determinants. Urban populations often have higher access to regulated healthcare but face increased exposure to clinical AMR. Rural populations are more likely to self-medicate or rely on untrained providers, exacerbating the misuse of antibiotics. The review by Ljungqvist et al. [1] highlights the need for public education and behavior change interventions tailored to different community contexts.

Furthermore, policy and surveillance gaps in rural areas delay detection and response to AMR outbreaks. While urban centers are typically included in national AMR surveillance networks, rural regions remain underrepresented. As such, emerging AMR hotspots in rural areas may go unnoticed until they reach clinical settings. Table 1 summarizes the key comparative dimensions between urban and rural AMR patterns.

In both contexts, a One Health approach is essential. The movement of resistance genes and bacteria between human, animal, and environmental reservoirs necessitates integrated solutions. For instance, hospital-based interventions must be complemented by policies targeting antimicrobial use in agriculture, environmental monitoring, and public education, particularly in rural communities. Machine learning models, like those proposed by Wu et al. [9], can enhance surveillance by predicting AMR hotspots based on environmental variables. These tools are especially valuable in low-resource rural settings, where conventional monitoring is challenging.

Table 1. Comparative Overview of AMR Characteristics in Urban vs Rural Areas

Dimension	Urban Areas	Rural Areas
Primary AMR Sources	Hospitals, sewage effluents, densely populated areas	Rivers, livestock farms, informal healthcare, agricultural runoff
Common Resistant Pathogens	ESBL- and carbapenem-resistant *E. coli*, *K. pneumoniae*, *A. baumannii*	*E. coli*, *Salmonella*, environmental bacteria with ARGs
Antibiotic Use Patterns	Frequent, often regulated; hospital-based prescriptions	Often unregulated; use in livestock and self-medication
Surveillance Coverage	Moderate to high; part of national AMR networks	Low or absent; underreported and poorly monitored
Socioeconomic Drivers	High density, better access to health infrastructure	Limited education, sanitation, and healthcare access
AMR Interventions	Stewardship programs, infection control, diagnostics	Limited interventions; need for environmental and community-level actions

Addressing AMR requires context-specific strategies that recognize the differing yet interconnected drivers in urban and rural ecosystems. Equity in surveillance, regulation, and healthcare infrastructure is critical for managing the AMR threat on a national and global scale.

6 Conclusions and Recommendations

Antimicrobial resistance (AMR) is a global public health concern that manifests differently across urban and rural settings due to variations in clinical practices, environmental exposures, antibiotic use patterns, and socioeconomic factors. This comparative study highlights that while urban areas face a concentrated burden of clinically significant resistant infections—particularly in hospital settings—rural areas serve as persistent and often overlooked reservoirs of resistance, driven by environmental contamination and agricultural antibiotic use. Urban regions tend to benefit from structured surveillance systems, established stewardship protocols, and better healthcare access. However, high antibiotic consumption, inadequate infection control, and overburdened hospitals contribute to the rapid emergence and dissemination of resistant pathogens. Conversely, rural regions suffer from limited diagnostic capacity, poor sanitation, and widespread informal antibiotic use, all of which create favorable conditions for environmental and zoonotic transmission of AMR.

Based on this analysis, the following key recommendations are proposed:

1. Expand AMR Surveillance to Rural Areas - National AMR monitoring systems must incorporate rural environmental and community health data to ensure early detection and localized interventions.
2. Strengthen Antimicrobial Stewardship in All Healthcare Settings - Stewardship programs should be scaled to include rural clinics and informal providers, supported by training and standardized guidelines.
3. Regulate and Monitor Antibiotic Use in Agriculture - Enforcement of regulations on veterinary antibiotics, combined with awareness campaigns for farmers, is essential to limit agricultural contributions to AMR.
4. Promote Public Education and Community Engagement - Tailored educational campaigns should address self-medication, hygiene, and rational antibiotic use, especially in low-literacy rural populations.
5. Support Research and Predictive Modeling - Investment in environmental microbiology and machine learning tools can help identify emerging AMR hotspots and inform risk-based decision-making.
6. Adopt a One Health Approach Across Policy Levels - AMR containment strategies must integrate human, animal, and environmental health sectors for a holistic response, particularly at the local governance level.

Effective AMR control requires equitable investment in infrastructure, education, policy, and research across both urban and rural areas. Bridging the surveillance and response gap between these regions is critical to preventing the silent spread of resistance and ensuring long-term public health security.

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