

<https://doi.org/10.59298/NIJRMS/2026/7.2.6266>

# **A Comprehensive Review of Urban-Rural Disparities in Water Resource Management and Their Implications for Malaria Transmission, Prevention, and Control Strategies in Sub-Saharan Africa**

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## **ABSTRACT**

Malaria remains a major public health challenge in Sub-Saharan Africa, with water resource management (WRM) playing a central role in its transmission dynamics. The urban-rural disparities in WRM contribute significantly to the differences in malaria burden between these areas. In urban regions, better-developed water infrastructure and sanitation systems often limit mosquito breeding sites, reducing malaria transmission. However, rapid urbanization and informal settlements in cities introduce pockets of vulnerability, where inadequate waste management and water drainage still contribute to mosquito proliferation. Conversely, rural areas are marked by a reliance on untreated surface water sources and poor sanitation infrastructure, creating ideal conditions for mosquito breeding. The lack of efficient WRM in these communities exacerbates the malaria burden, as inadequate water access and sanitation increase mosquito breeding grounds and limit access to effective malaria control interventions. This review explores the role of urban-rural disparities in WRM, highlighting their influence on malaria transmission, prevention, and control strategies. By analyzing these disparities, the review proposes policy interventions and community-based solutions to improve WRM and sanitation in rural regions, thereby reducing malaria risks. Addressing the gaps in WRM across both urban and rural contexts is crucial for achieving sustainable malaria control in Sub-Saharan Africa.

**Keywords:** Urban-rural disparities, water resource management, malaria transmission, malaria prevention.

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## **INTRODUCTION**

Malaria continues to pose a significant public health challenge globally, particularly in sub-Saharan Africa, where it is responsible for approximately 200 million reported cases annually [1]. The disease, transmitted by the bite of infected Anopheles mosquitoes that breed in stagnant water, is closely linked to environmental factors, especially the management of water resources. Effective Water Resource Management (WRM) is crucial for malaria prevention, as it minimizes mosquito breeding sites through clean water systems and sanitation initiatives [2]. However, urban and rural areas experience a stark contrast in water management and sanitation infrastructure, with urban locations generally possessing better access to clean water and efficient waste management. This disparity plays a significant role in influencing malaria transmission, as urban settings can implement more effective control measures, reducing the risk of outbreaks [3]. Conversely, rural areas often struggle with inadequate infrastructure, leading to limited access to safe drinking water and poor sanitation, which fosters mosquito breeding. The lack of proper waste management and unreliable water supplies in rural regions increases vulnerability to malaria, as populations resort to unsafe water sources that exacerbate mosquito proliferation [4]. This review aims to analyze how these urban-rural disparities in water resource management affect malaria burden across Sub-Saharan Africa. It will explore the intricate relationship between WRM, sanitation conditions, and malaria transmission, offering

insights into solutions and recommendations for addressing these disparities to improve water management and sanitation efforts, thereby mitigating malaria risks in vulnerable communities [5].

Malaria is caused by *Plasmodium* parasites, which are transmitted to humans through the bites of infected *Anopheles* mosquitoes. The disease is characterized by fever, chills, and flu-like symptoms, and if left untreated, it can lead to severe complications and death [6]. In Sub-Saharan Africa, malaria remains one of the leading causes of morbidity and mortality, with young children and pregnant women being the most vulnerable populations. The disease is endemic in most African countries, with seasonal spikes in transmission corresponding to changes in rainfall patterns, which affect mosquito populations and their breeding sites. Water is a critical factor in the life cycle of *Anopheles* mosquitoes [7]. Female mosquitoes lay their eggs in stagnant water, where the larvae develop into adult mosquitoes that can subsequently spread the parasite. Thus, controlling the availability and management of water resources is essential for malaria prevention [8]. This relationship highlights the importance of effective water resource management (WRM) in both urban and rural settings. In urban areas, water infrastructure is generally more developed, with greater access to piped water, well-maintained drainage systems, and waste management services. These factors reduce the availability of stagnant water bodies and consequently limit mosquito breeding sites [9]. However, rapid urbanization in many parts of Sub-Saharan Africa has led to overcrowding and the expansion of informal settlements, where water supply and sanitation infrastructure often remain inadequate. In these settlements, the lack of proper waste management and drainage systems creates ideal conditions for the proliferation of mosquitoes. On the other hand, rural areas often face more acute challenges in terms of water management [10]. Many rural communities rely on surface water sources, such as rivers and ponds, which are more prone to contamination and offer abundant breeding sites for mosquitoes. Inadequate sanitation infrastructure, limited access to safe drinking water, and poor waste disposal systems contribute to the higher malaria burden in these areas. Without efficient water resource management systems, rural populations remain at heightened risk of malaria transmission [11].

Despite the availability of malaria prevention tools, such as insecticide-treated nets (ITNs), indoor residual spraying (IRS), and antimalarial medications, the disease continues to be a leading cause of death and illness in Sub-Saharan Africa. The effectiveness of these interventions is greatly influenced by environmental factors, particularly water management. In Sub-Saharan Africa, there is a clear urban-rural divide in water resource management, sanitation infrastructure, and access to clean water, which plays a significant role in malaria transmission dynamics [12]. The disparities in WRM between urban and rural areas exacerbate the burden of malaria in rural regions, where inadequate water and sanitation systems contribute to an increase in mosquito breeding sites. As a result, rural populations are often more exposed to malaria transmission, with limited access to effective prevention and control measures [13]. These disparities are further compounded by limited resources, poor governance, and a lack of infrastructure development in rural areas. Addressing these disparities is crucial for achieving malaria control and eventually eliminating the disease in Africa [14].

The study aims to investigate the disparities in water resource management (WRM) and sanitation infrastructure between urban and rural areas of Sub-Saharan Africa, with a specific focus on their impact on malaria transmission dynamics. One of its key objectives is to examine how differences in water management practices influence mosquito breeding sites and, consequently, the prevalence of malaria in both urban and rural contexts. Additionally, the study seeks to explore the critical role of sanitation systems in controlling malaria, considering how inadequate waste management and poor water access contribute to the creation of breeding environments for mosquitoes. Another objective is to assess the effectiveness of current malaria prevention strategies, aiming to identify key gaps in the urban-rural divide and propose evidence-based solutions to address these disparities. By investigating these factors, the research also aims to identify policy interventions that could enhance water and sanitation systems in rural communities, where malaria transmission remains a persistent challenge. The significance of this study lies in its potential to inform more targeted, context-specific malaria control measures that can address the unique challenges faced by rural populations. By improving WRM and sanitation, the study will contribute to achieving long-term reductions in malaria transmission, ultimately supporting broader public health goals across the region.

#### **Water Resource Management in Urban and Rural Areas**

Water Resource Management (WRM) in both urban and rural areas of Sub-Saharan Africa presents unique challenges, particularly in terms of access to clean water and sanitation. In urban areas, centralized water supply systems, typically managed by municipal governments or utility companies, provide a more reliable and treated water source [15]. However, rapid urbanization and population growth put immense pressure on these systems, sometimes leading to inadequate coverage, especially in informal settlements (slums). These settlements, often neglected by formal water and sanitation infrastructure, are prone to improper waste disposal and poor drainage, creating stagnant water sources that serve as breeding grounds for *Anopheles* mosquitoes, the vector for malaria [16]. Urban areas, despite having better overall sanitation infrastructure, still struggle with these informal settlements, which are left vulnerable to waterborne diseases and malaria transmission. In contrast, rural areas face

more severe challenges due to less centralized water management. Rural communities often depend on surface water sources like rivers, lakes, and ponds, which are easily contaminated by agricultural runoff, livestock waste, and poor sanitation practices. Water scarcity is compounded by climate change and droughts, increasing the reliance on unsafe water sources [17]. Furthermore, inadequate waste management infrastructure contributes to the proliferation of mosquito breeding habitats. Traditional water sources and methods, which are often used in rural households, further complicate efforts to reduce malaria risk.

### **Implications of WRM Disparities on Malaria Transmission**

Disparities in water resource management (WRM) between urban and rural areas have profound implications on malaria transmission. Stagnant water is the primary breeding ground for Anopheles mosquitoes, which transmit malaria. In urban areas with better infrastructure and more consistent WRM practices, the availability of controlled and treated water, along with proper sanitation, limits the number of stagnant water sources where mosquitoes can breed [18]. This results in fewer breeding sites and, consequently, a lower burden of malaria. However, poor urban planning, informal settlements, and inadequate waste management in some cities can still create pockets of high-risk environments, where water stagnates and mosquito breeding flourishes. In contrast, rural areas face greater challenges. Limited access to clean water and sanitation exacerbates the problem, as open water sources, such as ponds, swamps, and unprotected wells, are more common [19]. These areas also tend to have less effective malaria control programs due to logistical constraints, including poor road infrastructure, fewer healthcare facilities, and limited resources. Consequently, malaria transmission rates are significantly higher in rural areas, where populations are more vulnerable and harder to reach with prevention efforts. These disparities underscore the urgent need for equitable and effective WRM strategies to curb malaria transmission, particularly in underserved rural regions [20].

### **Water Resource Management and Malaria Control Strategies**

Water resource management (WRM) and malaria control strategies are inextricably linked, with effective water management playing a crucial role in reducing malaria transmission. In rural areas, improving access to safe and clean water reduces reliance on unsafe water sources that often attract mosquitoes. Additionally, integrated approaches such as pest management, waste management, and water treatment initiatives can significantly decrease mosquito breeding habitats [21]. Proper sanitation and well-maintained drainage systems are key in mitigating stagnant water pools that serve as breeding grounds for malaria vectors. Furthermore, urban planning, particularly in informal settlements, should prioritize infrastructure that ensures clean water access and effective sanitation to prevent the formation of malaria hotspots. This combined approach of water management and vector control is essential for sustainable malaria prevention. The impact of climate change further complicates both WRM and malaria control [22]. Variations in precipitation patterns, temperature changes, and droughts are altering water resource availability in Sub-Saharan Africa. In rural areas already facing water scarcity, these shifts exacerbate challenges in providing both domestic water and resources necessary for malaria prevention. Climate change also influences mosquito populations, as Anopheles mosquitoes thrive in warmer temperatures and stagnant water [23]. Urban areas may see more localized water shortages due to climate-induced floods, creating new breeding sites. Thus, adaptive WRM strategies must address these challenges, integrating climate resilience into malaria control measures.

### **Policy, Governance, and Community-Based Approaches**

Urban-rural disparities in water resource management (WRM) and malaria transmission are often exacerbated by governance issues such as weak policy enforcement, corruption, and insufficient coordination between water management and health sectors. In many regions, especially rural areas, governance structures can be fragmented, making it difficult to address the interconnected challenges of water scarcity, poor sanitation, and malaria [24]. To tackle these issues, effective malaria control requires a holistic, multi-sectoral approach that integrates water resources, public health, and local governance. This coordination ensures that malaria prevention measures are well-targeted and sustainable. Community-based approaches play a crucial role in rural settings, where formal governance mechanisms may be less effective [25]. When local communities are actively involved in water management and malaria prevention, they develop a sense of ownership and accountability, which can lead to better maintenance of water infrastructure, improved sanitation, and more effective malaria control practices. Furthermore, these community-led efforts can promote public awareness of how water resources, sanitation, and malaria transmission are interlinked, leading to empowered communities that are more proactive in adopting preventive measures, such as using bed nets, ensuring clean water access, and improving drainage systems to reduce mosquito breeding sites [26].

## **CONCLUSION**

The disparities in water resource management (WRM) between urban and rural areas in Sub-Saharan Africa are significant contributors to the varying malaria burdens in these regions. Urban centers, although equipped with more developed water supply systems, struggle with challenges such as rapid population growth, informal settlements, and inadequate infrastructure. In contrast, rural areas face a lack of access to clean water and proper

sanitation, which exacerbates the risks of malaria transmission. Integrated approaches, addressing both WRM and vector control, are essential to combat malaria effectively. Policymakers must prioritize equitable water management, enhanced sanitation systems, and climate change adaptation strategies in their malaria control efforts. Bridging the gap between urban and rural WRM is pivotal in reducing malaria transmission. To this end, recommendations include policy integration, infrastructure development, climate adaptation strategies, community empowerment, and strengthened monitoring and evaluation systems. By implementing these recommendations through collaborative, targeted interventions, substantial progress can be achieved in reducing the malaria burden in Sub-Saharan Africa.

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**CITE AS: Tom Robert. (2026). A Comprehensive Review of Urban-Rural Disparities in Water Resource Management and Their Implications for Malaria Transmission, Prevention, and Control Strategies in Sub-Saharan Africa. NEWPORT INTERNATIONAL JOURNAL OF RESEARCH IN MEDICAL SCIENCES, 7(2):62-66**  
<https://doi.org/10.59298/NIJRMS/2026/7.2.6266>