

# Advancements in Diarrhea Control Strategies in Africa: Current Approaches and Emerging Technologies

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## ABSTRACT

Diarrheal disease remains a leading cause of morbidity and mortality among children under five across Africa, driven by gaps in water, sanitation, and hygiene (WASH), limited access to timely treatment, and uneven vaccine coverage. In the last decade, control strategies have combined long-established clinical interventions (oral rehydration, zinc, breastfeeding, rotavirus vaccination) with innovations in diagnostics, surveillance, digital health, and sanitation engineering. This review synthesizes recent progress and emerging technologies relevant to African settings: expansion of rotavirus vaccine introductions and supply mechanisms; efforts to scale up co-packaged oral rehydration solution (ORS) and zinc; development and deployment of point-of-care and multiplex molecular diagnostics; wastewater-based epidemiology and environmental surveillance; and novel water- and sanitation-focused technologies (point-of-use treatment, container-based sanitation, improved fecal sludge management). We highlight implementation barriers (supply chains, health system capacity, behavior change, financing) and identify research and policy priorities needed to accelerate impact, including cost-effective diagnostic algorithms, integrated surveillance platforms, sustainable financing for WASH, and locally adapted delivery strategies.

**Keywords:** Diarrhea Control, Africa, Current Approaches, Emerging Technologies

## INTRODUCTION

Diarrheal disease remains a significant public health concern in Africa, representing one of the leading causes of morbidity and mortality, particularly among children under five years of age. Despite decades of global and regional efforts to reduce its impact, diarrheal diseases continue to account for hundreds of thousands of preventable deaths each year in sub-Saharan Africa [1]. A broad spectrum of bacterial, viral, and parasitic pathogens, including *Escherichia coli*, *Shigella* species, *Salmonella* species, rotavirus, norovirus, and *Giardia lamblia*, among others causes these illnesses. The burden is disproportionately borne by young children, malnourished individuals, and populations with limited access to safe water, adequate sanitation, hygiene (WASH) infrastructure, and timely healthcare interventions [2].

The African continent faces unique challenges that perpetuate the high burden of diarrheal disease. Inadequate access to potable water, poor sanitation infrastructure, and insufficient hygiene practices create conditions that facilitate the transmission of diarrheal pathogens. In addition, healthcare access disparities and delayed treatment further exacerbate morbidity and mortality, particularly in rural and peri-urban areas [3]. Oral rehydration therapy (ORT), zinc supplementation, and exclusive breastfeeding have historically been central to diarrheal management and have saved millions of lives. However, these traditional interventions, while effective, are often undermined by challenges in supply chains, caregiver awareness, and health system capacity [4].

Over the last decade, advances in scientific research and technology have provided new tools to enhance diarrheal prevention, diagnosis, and treatment. Expanded rotavirus vaccine coverage, point-of-care diagnostics, molecular multiplex testing, and digital health interventions have demonstrated potential to transform the landscape of diarrheal control in African settings [5]. Moreover, innovations in environmental surveillance, such as wastewater-based epidemiology, and new sanitation technologies, including container-based sanitation and improved fecal sludge management, offer additional avenues to interrupt transmission and reduce disease incidence. These

developments reflect an integrated approach, recognizing that diarrhea control requires a combination of clinical, technological, behavioral, and environmental strategies [6].

Despite the availability of effective interventions, diarrheal diseases remain a persistent threat in Africa, contributing significantly to under-five mortality rates and chronic childhood malnutrition. According to the World Health Organization (WHO) and UNICEF, diarrheal diseases are among the top three causes of death for children under five in sub-Saharan Africa, responsible for an estimated 500,000 deaths annually [7]. Stagnation in progress can be attributed to several interconnected factors. First, inequities in access to safe water, sanitation, and hygiene perpetuate pathogen exposure. Second, gaps in healthcare infrastructure and human resources limit timely diagnosis and treatment, reducing the effectiveness of ORS, zinc, and vaccination programs. Third, implementation challenges, such as weak supply chains, insufficient funding, and socio-cultural barriers, undermine the scale-up of both traditional and emerging interventions [8].

Furthermore, new challenges are emerging with changing climate patterns, rapid urbanization, and population growth, which contribute to increased vulnerability to waterborne diseases. Urban slums, where WASH infrastructure is inadequate and overcrowding is common, represent hotspots for diarrheal outbreaks [9]. Additionally, emerging pathogens and shifting epidemiological patterns necessitate enhanced surveillance and adaptive response strategies. Without an integrated approach that combines prevention, rapid diagnosis, and treatment with innovative technologies, the continent will struggle to meet global child health targets, including the Sustainable Development Goal (SDG) 3.2, which aims to end preventable deaths of newborns and children under five. [10]

This review provides a comprehensive synthesis of current and emerging strategies for diarrhea control in Africa. It aims to assess traditional prevention and management interventions, such as oral rehydration solution (ORS), zinc supplementation, exclusive breastfeeding, and vaccination, while examining new technological approaches, including molecular diagnostics, wastewater surveillance, and digital health tools. The study also evaluates innovations in water, sanitation, and hygiene (WASH) systems, such as point-of-use water treatment and improved fecal sludge management. Guided by key research questions, it explores the effectiveness of existing interventions, the potential of emerging technologies, integration of WASH with clinical solutions, barriers to implementation, and priorities for research and policy. The review's significance lies in its potential to inform policymakers, healthcare providers, and researchers on strengthening diarrhea control programs, reducing child morbidity and mortality, and promoting sustainable health interventions. By highlighting Africa-specific challenges and solutions, it advocates for context-driven, multi-sectoral collaboration among health systems, technology developers, and community stakeholders. Ultimately, the review underscores that combining traditional methods with innovative technologies can accelerate progress toward reducing diarrheal disease burden, enhancing child survival, and advancing broader goals of health equity, resilience, and sustainable development across Africa.

#### **Burden and why new approaches are needed**

Despite remarkable global progress in reducing under-five mortality from diarrheal diseases, the burden remains disproportionately high in many parts of Africa, where it continues to cause a significant number of clinic visits, hospitalizations, and deaths. Diarrhea not only threatens child survival but also undermines growth, cognitive development, and long-term productivity, perpetuating cycles of poverty and poor health [11]. The persistence of this challenge is largely attributed to inequalities in access to clean water, sanitation, and hygiene (WASH) facilities, as well as uneven coverage of vaccines such as rotavirus. Inadequate healthcare-seeking behaviors, limited access to oral rehydration therapy and zinc supplementation, and fragile healthcare systems further exacerbate the problem. Additionally, the rising threat of antimicrobial resistance (AMR) among enteric pathogens is reducing the effectiveness of conventional treatments, complicating case management and increasing mortality risks. Climate change also poses new challenges by altering rainfall patterns, water availability, and contamination pathways, heightening the risk of waterborne infections. These interlinked factors underscore the urgent need for innovative, integrated approaches that combine technological advances in diagnostics and surveillance with strengthened preventive infrastructure, community-based interventions, and equitable access to WASH and healthcare services to sustainably reduce the burden of diarrheal disease in Africa [12].

#### **Established clinical and public-health measures: status and recent progress**

Established clinical and public-health measures have played a critical role in reducing diarrheal morbidity and mortality among children in sub-Saharan Africa, yet significant gaps remain. Oral rehydration therapy (ORS) combined with zinc supplementation continues to be the cornerstone of diarrheal disease management, offering an effective, low-cost solution to prevent dehydration and enhance recovery. Despite its proven efficacy, recent pooled analyses reveal that the co-utilization of ORS and zinc among children under five years old remains suboptimal, with an overall coverage of about 44% across the region. Utilization disparities are largely influenced by factors such as maternal education, access to health information through media, health insurance coverage, and proximity to healthcare facilities. Strengthening the supply chain and scaling up co-packaged ORS and zinc distribution are

therefore key priorities [13]. Similarly, vaccination programs, particularly rotavirus immunization supported by Gavi and partners, have made substantial progress in preventing severe diarrhea and reducing hospitalizations. Continued efforts aim to enhance immunization coverage, maintain reliable vaccine supply chains, and ensure cold-chain infrastructure, while exploring newer vaccine formulations suited to local contexts. Together, these measures form the foundation of integrated strategies to combat diarrheal diseases and improve child health outcomes across Africa.

#### **Emerging diagnostics and surveillance technologies**

Emerging diagnostics and surveillance technologies are revolutionizing the detection and management of enteric diseases, particularly in low- and middle-income countries (LMICs). Point-of-care (POC) tests and rapid diagnostics have made significant progress in enabling timely, affordable, and field-adapted detection of infections. These innovations allow clinicians to distinguish between viral and bacterial causes, thereby improving treatment accuracy and reducing inappropriate antibiotic use [14]. Non-invasive POC tests, biomarker-based methods, and multiplex assays capable of detecting multiple pathogens with high sensitivity are transforming disease management. However, implementation challenges persist, including high costs, minimal laboratory infrastructure requirements for certain molecular platforms, and difficulties in interpreting results that distinguish colonization from active infection. Multiplex molecular assays, such as PCR panels and cartridge-based platforms, further enhance diagnostic precision by identifying several pathogens from a single specimen, contributing to improved outbreak response and epidemiologic insight. Despite their promise, their widespread use is constrained by cost and maintenance needs. Additionally, wastewater-based epidemiology (WBE) and environmental surveillance are emerging as powerful population-level tools for early detection of enteric viruses like rotavirus, norovirus, and adenovirus. WBE complements clinical surveillance, especially in areas with limited health infrastructure, although scaling up these technologies requires investment in laboratory capacity and infrastructure development [15].

#### **Water, sanitation, and hygiene (WASH) innovations**

Water, sanitation, and hygiene (WASH) innovations are essential for improving public health, particularly in low-resource and densely populated settings. Point-of-use (POU) water treatment technologies such as household filters, chlorine dispensers, solar disinfection (SODIS), and ceramic filters provide affordable and effective means to reduce pathogen exposure and ensure safe drinking water [16]. However, evidence shows that technology alone cannot guarantee success; sustained behavior change, regular maintenance, and reliable access to replacement parts are equally critical for long-term impact. In areas where sewer systems are unfeasible, container-based sanitation (CBS) and improved fecal sludge management (FSM) systems offer practical and scalable alternatives. These innovations help minimize environmental contamination, enhance safety and dignity, and enable opportunities for resource recovery, such as biogas and fertilizer production. Furthermore, community-led and systems-based approaches that integrate WASH interventions with nutrition, vaccination, and primary healthcare initiatives have demonstrated strong potential for sustainable improvements. Strengthening the role of community health workers and leveraging schools as platforms for hygiene education fosters lasting behavior change and reduces diarrheal diseases [17]. Collectively, these WASH innovations highlight the importance of combining technological, social, and institutional strategies to achieve comprehensive, resilient, and equitable improvements in water and sanitation outcomes.

#### **Digital Health, Data Systems, and Decision Support**

Digital health technologies are revolutionizing healthcare delivery and disease management across Africa, offering innovative solutions to bridge systemic gaps in surveillance, diagnosis, and treatment. Mobile health (mHealth) applications, electronic health records, and geographic information systems (GIS) have become essential tools for improving the efficiency and accuracy of healthcare systems. Through these platforms, community health workers (CHWs) can access up-to-date treatment guidelines, receive alerts for disease outbreaks, and monitor patient progress in real time, all of which enhance clinical decision-making, especially in rural and underserved areas. Electronic reporting systems facilitate faster case detection and data sharing, allowing public health authorities to respond swiftly to emerging threats [18]. Furthermore, the integration of clinical and environmental datasets, including wastewater-based epidemiology (WBE) signals, supports predictive modeling and proactive interventions before outbreaks escalate. Strengthening data infrastructure, ensuring interoperability between digital systems, and investing in training for health workers are vital for maximizing the benefits of these technologies. Improved digital visibility across health supply chains also ensures better forecasting, procurement, and distribution of essential commodities like oral rehydration salts (ORS), zinc supplements, and vaccines, ultimately leading to more resilient and responsive healthcare systems capable of addressing both communicable and non-communicable diseases.

#### **Implementation Challenges and Barriers**

Despite significant progress in global child health initiatives, multiple implementation challenges continue to impede the widespread adoption of diarrheal disease prevention and treatment interventions across low- and middle-income countries, including Uganda. Supply chain weaknesses and inadequate financing remain among the most pressing issues [19]. Persistent vaccine shortages, inconsistent availability of oral rehydration salts (ORS) and zinc, and

insufficient funding for large-scale water, sanitation, and hygiene (WASH) infrastructure limit program scalability and sustainability. Reports from UNICEF and Gavi highlight ongoing logistical and readiness barriers that slow national rollouts. Health system capacity also varies widely, with disparities in routine immunization coverage, community case management, and laboratory diagnostic capabilities affecting overall program effectiveness. Moreover, behavioral and cultural factors play a critical role; caregiver knowledge, perceptions of ORS and zinc therapy, and local health-seeking behaviors directly influence uptake rates. Studies show that maternal education and media exposure are strong predictors of increased co-utilization of ORS and zinc. Additionally, while molecular diagnostics and multiplex panels offer advanced disease surveillance and pathogen identification, their high costs, consumable requirements, and maintenance demands hinder their use in resource-limited settings. [20] Addressing these barriers requires coordinated policy reforms, sustainable funding models, and community-driven engagement strategies.

### **Policy, Programmatic Recommendations, and Future Research Directions**

Effective management of diarrheal diseases and other enteric infections in Africa requires a holistic policy and programmatic approach grounded in evidence-based, scalable, and sustainable strategies. Governments and partners should prioritize the expansion of proven, cost-effective interventions such as oral rehydration salts (ORS) and zinc co-packs, alongside the introduction of rotavirus vaccines and the maintenance of high immunization coverage. Surveillance systems need to be layered, combining facility-based data with environmental monitoring (including wastewater surveillance) and syndromic reporting to detect outbreaks early and respond effectively. Adoption of context-appropriate diagnostics, including rapid point-of-care (POC) tests and cost-efficient molecular tools, is essential for accurate case identification and outbreak control. Furthermore, investment in urban sanitation and fecal sludge management (FSM), especially in informal settlements, can substantially reduce environmental contamination and disease transmission. Strengthening implementation research [21], fostering local manufacturing capacity for diagnostics, vaccines, and WASH technologies, and integrating digital tools for supply-chain visibility and community health worker support are critical for long-term impact.

Future research should focus on cost-effectiveness analyses of advanced diagnostics versus syndromic management, operationalizing wastewater-based epidemiology, testing ORS/zinc distribution models, assessing decentralized sanitation business approaches, and evaluating the safety and feasibility of novel therapeutics such as microbiome and phage-based therapies in low- and middle-income settings.

### **CONCLUSION**

Diarrheal diseases remain a major public health challenge in Africa, disproportionately affecting children under five and contributing to high morbidity and mortality. While traditional interventions, such as oral rehydration salts (ORS), zinc supplementation, exclusive breastfeeding, and rotavirus vaccination, have saved countless lives, coverage gaps, health system limitations, and inequities in water, sanitation, and hygiene (WASH) infrastructure continue to hinder progress. Recent advancements in diagnostics, surveillance, digital health, and sanitation technologies offer new opportunities to enhance prevention, early detection, and timely treatment. Integrating point-of-care and molecular diagnostics, wastewater-based epidemiology, container-based sanitation, and digital health platforms can strengthen both community- and facility-level responses. Policy and programmatic strategies emphasizing scalable, context-appropriate interventions, strengthened supply chains, local manufacturing, and community engagement are essential for sustainable impact. Moving forward, research on cost-effectiveness, implementation models, and novel therapeutics will be critical to guide evidence-based decision-making. A multi-sectoral, integrated approach combining established and emerging strategies is pivotal to reducing diarrheal disease burden, improving child survival, and achieving equitable health outcomes across Africa.

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