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Genomic Surveillance and Environmental risk Mitigation For Cholera Control in Africa

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In 2024, a total of 486,760 cholera and acute watery diarrhea (AWD) cases, along with 4,018 deaths, were reported globally across five WHO regions (WHO, 2024), with Africa experiencing the highest burden (Siamalube et al., 2024). As of November 24, 2024, the African Region alone recorded 150,156 cases across 18 countries, with the Democratic Republic of the Congo (28,804 cases), Ethiopia (26,718 cases), and Zambia (20,219 cases) reporting the highest numbers. During the same period, 2,853 deaths were reported across 17 countries, with Nigeria (702 deaths), Zambia (637 deaths), and the Democratic Republic of the Congo (409 deaths) accounting for the majority of fatalities (WHO, 2024). These trends underline the necessity for improved surveillance, resource allocation, and tailored interventions to address the disparities in cholera management across the region.

Cholera outbreaks in Africa are fundamentally both an environmental and genomic issue, with various interconnected factors driving the disease burden. Environmental and climate-related factors such as floods, droughts, and population displacement due to conflict have exacerbated cholera transmission in many African regions (Charnley et al., 2021). For instance, the lack of access to clean water and adequate sanitation significantly increases cholera risk, with the 2023 Africa Sustainable Development Report revealing that 411 million people in Africa still lack access to safe water (United Nations Development Programme, 2023). Additionally, rapid urbanization, weak health systems, and limited vaccination coverage further complicate efforts to mitigate cholera outbreaks. These environmental factors, compounded by climate change, have magnified the disease's prevalence and severity, calling for urgent improvements in water, sanitation, and hygiene (WASH) systems, as well as real-time environmental monitoring, including water quality assessments (Ratnayake, 2024) and climate risk mapping (Kruger, Lorah and Okamoto, 2022).

On the genomic front, an often-overlooked driver of cholera outbreaks is the lack of comprehensive genomic data on Vibrio cholerae virulence in many African countries (Igere and Nwodo, 2024). Genomic studies have revealed critical insights into the rapid circulation of cholera lineages, such as the AFR15 lineage, which has been linked to large outbreaks in Southern Africa (Mboowa et al., 2024). These findings emphasize the need for coordinated regional surveillance and interventions, as genomic data can significantly enhance understanding of cholera's spread across borders. The identification of virulence factors such as Vibrio Pathogenicity Island-1 (VPI-1) and cholera toxin (CT) genes further highlights the complex molecular mechanisms driving cholera's clinical manifestations (Kumar, Das and Kumar, 2020). As V. cholerae exhibits genetic diversity and can acquire antimicrobial resistance genes through horizontal gene transfer (HGT), genomic surveillance becomes essential to track evolving strains and predict future outbreaks (Mevada et al., 2023).

The environmental and genomic dimensions of cholera outbreaks are intertwined and must be addressed together for effective control. Improving water, sanitation, and hygiene infrastructure, coupled with continuous genomic surveillance, will enable better prediction and management of cholera outbreaks. As genomic sequencing uncovers the transmission dynamics and virulence factors of V. cholerae, it becomes evident that a multi-faceted approach is needed. This includes strengthening the capacity for genomic data collection and analysis across African nations and integrating this with environmental monitoring systems. By doing so, African countries can build a robust surveillance system to mitigate the risks posed by both environmental factors and genomic variability, ultimately leading to more effective cholera prevention and control strategies.

Importance of Genomic Tools in tackling Cholera

Genomic tools have revolutionized our understanding and management of cholera outbreaks by providing critical insights into epidemiological tracking, antimicrobial resistance, and advancements in vaccines and diagnostics. Through phylogenetic analysis, the global spread of the seventh cholera pandemic has been meticulously traced, revealing transmission patterns and the establishment of endemic strains, which is instrumental in designing targeted interventions to halt disease spread (Ramamurthy et al., 2019). Concurrently, genomic studies have highlighted the alarming rise of antimicrobial resistance (AMR) in Vibrio cholerae, driven by mobile genetic elements such as plasmids, integrons, and transposons, which facilitate the proliferation of resistance genes and undermine the effectiveness of common treatments, necessitating the pursuit of novel therapies (Mevada et al., 2023). These genomic insights have also propelled vaccine development by identifying strain-specific antigens and virulence factors while enhancing molecular diagnostics to enable rapid identification of virulent or resistant strains during outbreaks. These advancements collectively support precise interventions, curtail disease transmission, and improve the timeliness of control measures (Lu et al., 2020).

Efforts of Africa so far in Genomics Surveillance

Africa's establishment of the Cholera Genomics Consortium (CholGEN) in 2022 has marked a pivotal step forward in combating cholera through the application of genomic surveillance. Led by the Africa CDC and the Africa Public Health Foundation, in collaboration with seven African Union Member States and global partners, CholGEN has made substantial progress in understanding the epidemiology of cholera (Mboowa, 2025). By sequencing over 1,000 samples, including 382 archived isolates, the project has revealed critical insights into cholera strain evolution and transmission (Africa CDC, 2024). These findings have informed more effective control strategies while enhancing genomic capacity in participating countries.

Additionally, the consortium's efforts have strengthened laboratory processes and introduced advanced bio-informatics tools, such as the Terra pipeline, to improve genomic analyses across the continent.

While CholGEN has achieved significant milestones, the initiative has also faced notable challenges that hinder its progress and highlight gaps in cholera genomic surveillance. Disparities in laboratory capacities across Member States, particularly in the recovery of archived Vibrio cholerae isolates, underscore the urgent need for standardized protocols and sustained capacity-building. Moreover, limited bioinformatics infrastructure and expertise in many countries remain obstacles to fully leveraging genomic tools (Pronyk et al., 2023). Logistical hurdles, especially in cross-border surveillance, further complicate coordinated cholera control efforts, while insufficient commitment and resources from national governments hinder the integration of genomic surveillance into broader public health systems (Buliva et al., 2023). These challenges underscore the need for continued investment and advocacy to ensure the project's success.

Beyond these operational barriers, genomics surveillance in resource-limited settings also presents technical challenges (Inzaule et al., 2021). Data ownership and governance remain critical concerns, as many African countries lack comprehensive frameworks to regulate genomics data collection, sharing, and use. The absence of clear policies raises concerns about potential misuse, particularly regarding patient confidentiality, consent, and equitable access to the benefits of genomic research. Additionally, genomic surveillance efforts may inadvertently introduce biases if sample collection is uneven across regions, disproportionately focusing on urban centers while neglecting rural and underserved communities where cholera remains endemic. Such biases could lead to incomplete epidemiological insights, limiting the effectiveness of targeted interventions.

Another pressing challenge is translating genomic findings into actionable public health interventions. While genomic sequencing can provide valuable insights into cholera transmission dynamics and antimicrobial resistance patterns, its real-world impact depends on effective data interpretation, communication, and integration into national disease control programs (Mboowa, 2025). Many public health agencies in resource-limited settings struggle with the technical capacity to interpret genomic data and apply it in outbreak response and policy formulation. This gap highlights the need for sustained investment not only in laboratory infrastructure but also in training multidisciplinary teams including epidemiologists, bioinformaticians, and policymakers to bridge the gap between research and practice.

Looking ahead, several critical tasks remain to achieve CholGEN's objectives. Enhancing laboratory capacities and bioinformatics infrastructure is essential, with mentorship programs and resource investments tailored to countries with lower capacities. Sustained advocacy is needed to integrate genomic surveillance into public health systems and secure funding for infrastructure, training, and operations. Additionally, strengthening cross-border collaboration through harmonized strategies and frequent regional engagements is vital for addressing transboundary outbreaks. By addressing these areas, CholGEN can build on its achievements, ensuring long-term success in controlling cholera and safeguarding public health in Africa.

Critical Challenges Hindering Genomic Surveillance in Africa

Genomic surveillance holds immense potential for reducing cholera prevalence in Africa, yet its implementation faces significant systemic challenges that impede its integration into disease prevention and management frameworks. One major obstacle is the lack of integrated data systems; without comprehensive electronic clinical and epidemiological records, correlating genomic data with disease trends becomes difficult, limiting actionable insights (Louie et al., 2007). Additionally, infrastructural deficiencies, such as the scarcity of advanced laboratory facilities and technological resources, restrict the ability to conduct high-throughput sequencing or analyze complex datasets, forcing reliance on external laboratories and delaying outbreak responses (Mulder et al., 2017). Financial burdens also hinder progress, as the high costs of reagents, consumables, and sequencing equipment coupled with logistical challenges create inconsistencies in laboratory operations (Alhaji Olono et al., 2024). Compounding these issues is a dependency on external funding, which, while essential, often undermines long-term sustainability and autonomy by aligning priorities with donor agendas rather than regional needs.

To overcome these barriers, significant investments in infrastructure and capacity building are essential. Governments and international partners must prioritize establishing well-equipped genomic laboratories and training skilled personnel to operate those (Onywera et al., 2024). Regional collaborations and data-sharing initiatives are equally important to ensure the swift exchange of information on cholera strains, facilitating early detection and coordinated responses. By addressing these systemic challenges, African nations can harness the full potential of genomic surveillance, transforming cholera control from a reactive approach into a proactive, data-driven strategy. This shift will not only reduce the burden of cholera but also enhance public health outcomes and build resilience against future outbreaks.

Tackling Environmental Determinants: The Role of WASH

The environmental determinants of cholera underscore the deep interconnection between health, infrastructure, and the environment. Improving WASH systems is not merely a public health intervention; it is a moral imperative. Communities plagued by recurrent cholera outbreaks often face the compounded burdens of poverty and systemic neglect. Strengthening WASH infrastructure not only curtails disease incidence but also promotes equity by enhancing the quality of life for vulnerable populations (McNeely et al, 2020). Furthermore, robust WASH systems increase resilience against climate-related disruptions, enabling communities to better withstand floods and droughts. Integrating WASH improvements with climate adaptation strategies such as flood-resistant sanitation designs and community water storage systems offers a comprehensive approach to mitigating cholera risks (Acharya and Silori, 2025). Ultimately, investing in WASH addresses the root causes of cholera, breaks the cycle of transmission, and paves the way for healthier, more equitable, and resilient communities. It is an investment in human dignity and the foundation for long-term public health (Peprah, 2017).

Bridging Genomic and Environmental Data: A Holistic Approach to Cholera Control

The current gap between genomic and environmental data is a critical weakness in cholera control efforts. Integrating real-time monitoring of water quality and climate data with genomic surveillance could provide a comprehensive view of cholera risks, enabling proactive responses rather than reactive containment. For instance, climate risk maps could predict areas prone to cholera outbreaks, allowing health authorities to allocate resources strategically. The disconnection between genomic and environmental data represents a pivotal weakness in the fight against cholera. While genomic surveillance excels in tracking the evolution and spread of cholera strains (Mboowa, 2025), it is limited in its ability to predict the environmental triggers that often precede outbreaks. On the other hand, environmental monitoring of factors such as water quality and climatic conditions provides critical context but lacks specificity in identifying outbreak dynamics.

Integrating these two data streams offers a transformative opportunity to enhance cholera control. Real-time monitoring of water quality, combined with genomic data, can identify hotspots where contamination coincides with the presence of virulent strains. Similarly, climate data, such as temperature fluctuations, rainfall patterns, and flood events, could be integrated into predictive models, creating climate risk maps that highlight areas prone to cholera outbreaks.

Such integration shifts the paradigm from reactive containment to proactive prevention. For instance, if climate risk maps identify regions at high risk due to impending floods, health authorities can deploy pre-emptive measures, such as setting up emergency water

treatment facilities, distributing hygiene kits, and conducting targeted community awareness campaigns. At the same time, genomic insights can inform vaccine deployment and the prioritization of high-risk populations for intervention.

To operationalize this system, robust data-sharing frameworks must be established to facilitate seamless collaboration between public health agencies, environmental monitoring bodies, and climate science institutions. Investments in interoperable digital platforms, such as cloud-based data repositories with real-time analytics dashboards, can enhance accessibility and usability. Furthermore, capacity-building initiatives should focus on training multidisciplinary teams including epidemiologists, data scientists, and environmental health professionals to interpret and act upon integrated data insights effectively. If the gap between genomic and environmental data is bridged, cholera control efforts will become more precise, timely, and effective, thereby, ultimately reducing the disease's impact on vulnerable populations and paving the way for more resilient health systems in Africa.

Breaking Down Silos: A Call for Multisectoral Collaboration

Cholera control in Africa has long struggled due to the siloed approach across health, environmental, climate, and genomic surveillance sectors (Carolina, 2022). Each sector has traditionally operated in isolation, focusing on their specific mandates and datasets without considering the broader, interconnected causes of cholera outbreaks. This fragmented approach fails to capture the complex interplay between environmental, climatic, and microbial factors that drive cholera spread, undermining the effectiveness of control efforts. For meaningful progress, a shift toward multisectoral collaboration is crucial, where data from health, environmental, climate, and genomic surveillance sectors are integrated into a unified system. By merging these data sets, we can gain a more holistic understanding of cholera dynamics, track its spread more effectively, and develop coordinated responses that address the root causes of outbreaks.

The path forward requires trust-building, transparent data-sharing frameworks, and joint efforts in developing tools that facilitate collaboration across these sectors. Aligning objectives and resources, alongside establishing collaborative governance structures, is essential for fostering effective coordination. This multisectoral approach, while technically necessary, also represents a moral imperative for mobilizing Africa's collective resources and expertise to combat cholera and enhance long-term public health. Key sectors like health, water, sanitation, climate, genomic surveillance, and local governance all have distinct roles in cholera control (Lee and Dodgson, 2017). Real-time data integration, joint training, and shared platforms for data exchange will enhance the efficiency of these efforts. As the sectors come together, collaborative governance and resource sharing will enable a unified, sustainable response to cholera, ensuring a more resilient and effective control strategy across Africa.

Policy and Advocacy: Sustaining the Momentum

A structured policy roadmap is essential for sustainable cholera control in Africa. In the short term (0–2 years), efforts should focus on strengthening genomic surveillance, improving public health preparedness, increasing community awareness, and implementing emergency WASH interventions. In the medium term (3–5 years), expanding WASH infrastructure, institutionalizing genomic surveillance, strengthening regional collaboration, and implementing policy reforms will be critical.

Sustaining long-term cholera control in Africa requires more than just technical innovations; it demands sustained political commitment and robust financial investment, particularly in countries like Nigeria where cholera outbreaks have been recurrent. While genomic surveillance and environmental risk mitigation hold transformative potential, their success depends on consistent funding and policy support. Advocacy plays a crucial role in this effort by highlighting the economic and social costs of cholera outbreaks, which extend beyond healthcare expenses to include lost productivity and the destabilizing impact on vulnerable populations(Cigudu,S, 2017).

By framing cholera control as a cost-effective investment, stakeholders can build a compelling case to secure the necessary financial resources. This includes lobbying for support for genomic laboratories, training programs, and improvements in water, sanitation, and hygiene (WASH) infrastructure. Regional collaboration can further reduce costs while expanding the reach of cholera control initiatives, making it a more efficient and impactful endeavour.

In addition to securing funding, policymakers must enact and enforce policies that support cholera control in the long run. This includes strengthening public health laws, prioritizing WASH infrastructure in national development plans, and integrating climate adaptation measures into health strategies. Advocacy efforts should be expansive, engaging a broad range of stakeholders from community leaders and civil society organizations to the media. Grassroots support is essential to keeping cholera control on political agendas and ensuring continuous attention and resources are allocated to the cause. By advocating for proactive, integrated cholera control systems, Africa can shift from reactive measures to long-term sustainable solutions. With a coordinated approach involving governments, development partners, and the private sector, Africa can reduce the cholera burden and foster healthier, more resilient communities (Agogo et al., 2019).

Integration as a Necessity: A Holistic Vision for Cholera Control

The integration of genomic surveillance and environmental risk mitigation is not simply an academic proposition; it is an urgent, practical necessity in the fight against cholera in Africa. Cholera outbreaks are a complex public health challenge, driven by a confluence of environmental factors such as unsafe water, inadequate sanitation, and broader climate conditions, alongside the microbial dynamics that genomic surveillance can reveal (Christaki et al., 2020). Addressing these root causes; poor sanitation, unsafe water, and environmental contamination through enhanced WASH (water, sanitation, and hygiene), infrastructure is crucial. This includes investments in modern water treatment facilities, rapid diagnostic tools such as PCR machines for cholera detection, and improved sanitation systems like bio-digesters. Additionally, capacity-building programs for public health workers on genomic surveillance techniques, laboratory diagnostics, and community-based early warning systems can enhance response efforts. It not only mitigates the immediate risk of cholera outbreaks but also lays the foundation for long-term resilience in affected communities. This proactive approach, when coupled with the precision of genomic surveillance, allows for the identification of cholera strains, tracking their spread, and anticipating outbreaks before they become unmanageable. In this way, genomic tools elevate the effectiveness of interventions, enabling tailored responses based on real-time data.

However, the true success of this integrated approach relies on the breaking down of sectoral silos that have traditionally impeded progress. The health, environmental, and climate sectors must shift from isolated operations to a unified model of partnership. This requires a concerted effort to share data, align objectives, and collaborate on interventions that are both timely and resource-efficient. The creation of joint platforms for data sharing and analysis will allow for a more nuanced understanding of cholera dynamics, ensuring interventions are tailored to the specific environmental and genomic context of each outbreak. Achieving this vision demands innovation, investment, and a willingness to collaborate across sectors. Policymakers, NGOs, scientists, and community leaders must unite to build a sustainable and enduring cholera control framework. By committing to this integrated strategy, Africa can not only reduce cholera's devastating impacts but also build a model of control that is resilient and adaptable, setting a precedent for global health efforts. The time to act is now through sustained collaboration and investment, Africa has the potential to transform cholera control and create a lasting impact that can be replicated worldwide.

Conclusion

Cholera remains a significant public health challenge across Africa, disproportionately affecting marginalized populations and exacerbated by structural, environmental, and systemic vulnerabilities. This article underscores the urgent need for integrated approaches to tackle cholera through improved Water, Sanitation, and Hygiene (WASH) systems, genomic surveillance, and environmental monitoring.

Genomic tools offer transformative potential for understanding cholera's transmission dynamics, antimicrobial resistance, and virulence, while environmental interventions address the root causes of outbreaks. However, the effectiveness of these solutions depends on overcoming critical challenges, including inadequate infrastructure, high costs, and siloed responses.

Ultimately, addressing cholera is not just a technical challenge but a moral imperative. Investing in resilient health systems and equitable infrastructure will save lives and build a foundation for sustainable development, public health security, and improved quality of life for the most vulnerable communities.

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