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Artificial Intelligence in Water, Sanitation and Hygiene in Sub-Saharan Africa: A Review of Applications, Opportunities and Challenges

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Abstract: Water, sanitation and hygiene (WASH) remain critical public health and development challenges in Sub-Saharan Africa (SSA), where approximately 440,000 deaths from diarrheal diseases were recorded in 2024 alone, primarily due to water contamination by fecal pathogens. In recent years, artificial intelligence (AI) and machine learning (ML) have emerged as transformative tools with the potential to address long-standing WASH challenges across the region. This review provides a comprehensive synthesis of the current state of AI applications in WASH across SSA, examining five key domains: water quality monitoring and prediction, sanitation infrastructure assessment, waterborne disease surveillance, citizen science and community engagement, and decision support for water resource management. Drawing upon peer-reviewed literature published between 2020 and 2026, alongside contemporary case studies from across the region, the review identifies significant opportunities including improved predictive accuracy for contamination events, scalable monitoring through remote sensing, and enhanced community participation through AI-powered tools while also highlighting persistent challenges, including data scarcity, infrastructural deficits, limited technical capacity, and ethical concerns around algorithmic governance. The analysis reveals that while AI-driven solutions have demonstrated substantial promise in research settings, translation to widespread operational deployment remains constrained by systemic barriers. We conclude by proposing a framework for responsible AI integration in WASH and identifying priority research directions for advancing resilient, equitable, and context-appropriate WASH services across Sub-Saharan Africa.

Keywords: *Artificial Intelligence; Machine Learning; Water Quality; Sanitation; Hygiene; Sub-Saharan Africa; WASH; Remote Sensing; Citizen Science; Predictive Modeling.*

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I. INTRODUCTION

Access to safe drinking water, adequate sanitation, and proper hygiene practices collectively referred to as WASH constitutes a fundamental determinant of public health and human development. Yet in Sub-Saharan Africa, these essential services remain persistently inadequate for vast segments of the population. As of 2024, approximately 2.1 billion people worldwide lack access to safely managed drinking water, and 3.4 billion lack safely managed sanitation (WHO and UNICEF, 2025). In Sub-Saharan Africa(SSA), the burden is disproportionately severe: diarrheal diseases caused approximately 434,000 deaths in Sub-Saharan Africa in 2021, mainly due to water contamination by fecal pathogens such as Escherichia coli. More recent estimates indicate that 440,000 deaths were recorded in 2024.

The persistence of these challenges reflects a complex interplay of factors: rapid urbanization outpacing infrastructure development, climate variability intensifying water scarcity and contamination risks, insufficient sanitation infrastructure, and chronic underinvestment in water and sanitation services. As Izah and Ogwu (2025) observe, water resources in the Global South are increasingly vulnerable to microbial contamination, and the challenge is exacerbated by rapid urbanization, climate variability, and insufficient sanitation infrastructure. The situation is further compounded by the fact that half of the population in SSA has no access to safe sanitation, with lack of sanitation linked to poor health, environmental degradation, and undermined social and economic development.

In this context, artificial intelligence has emerged as a potentially transformative set of technologies for addressing WASH challenges. AI encompasses a range of computational approaches including machine learning, deep learning, natural language processing, and computer vision that enable systems to learn from data, identify patterns, and make predictions or decisions with minimal human intervention. The application of AI to WASH in SSA has gained substantial momentum in recent years, driven by advances in computational power, the proliferation of mobile technologies, increasing availability of satellite and remote sensing data, and growing recognition of the limitations of conventional approaches.

This review aims to provide a comprehensive synthesis of AI applications in WASH across Sub-Saharan Africa. Specifically, we: (1) examine the current state of AI-driven WASH solutions across five key domains; (2) analyze the opportunities and demonstrated benefits of these approaches; (3) identify persistent challenges and barriers to adoption; and (4) propose a framework for responsible AI integration and priority research directions. In doing so, this review contributes to the growing imperative for leveraging digital technologies to accelerate progress toward Sustainable Development Goal 6 universal access to clean water and sanitation.

II. METHODOLOGY

➢ *Review Design*

This review adopts a systematic literature review methodology following established guidelines for WASH and digital health research. The review protocol was designed to capture peer-reviewed literature, conference proceedings, and authoritative institutional reports addressing AI/ML applications in WASH contexts within Sub-Saharan Africa.

➢ *Search Strategy*

Database searches were conducted across Scopus, Web of Science, PubMed, Google Scholar, and arXiv for publications between January 2020 and July 2026. The search strategy employed combinations of the following keywords and Boolean operators: ("artificial intelligence" OR "machine learning" OR "deep learning" OR "neural network") AND ("water quality" OR "sanitation" OR "hygiene" OR "WASH") AND ("Sub-Saharan Africa" OR "Africa" OR specific country names). Additional searches targeted specific applications including "remote sensing," "citizen science," "disease prediction," and "decision support." Reference lists of identified articles were manually screened to capture additional relevant publications.

➢ *Inclusion and Exclusion Criteria*

Articles were included if they met the following criteria: (1) published in peer-reviewed journals, conference proceedings, or authoritative institutional reports; (2) addressed AI/ML applications in WASH contexts; (3) focused on Sub-Saharan Africa or had direct relevance to the region; and (4) provided empirical data, analytical frameworks, or case studies. Articles were excluded if they focused exclusively on non-African contexts without transferable insights, or if they addressed AI applications unrelated to WASH. A total of 85 articles were identified for full-text review, with 52 meeting inclusion criteria and forming the evidence base for this synthesis.

III. THEORETICAL FOUNDATIONS: AI AND WASH IN THE GLOBAL SOUTH

➢ *The WASH Challenge in Sub-Saharan Africa*

The WASH crisis in Sub-Saharan Africa is characterized by spatial and social inequalities, inadequate infrastructure, and vulnerability to environmental stressors. In the sanitation sector, the rate of connection to sewerage systems does not exceed 77% in large cities and 45% in smaller urban areas. The gap is even more pronounced in rural areas, where conventional sanitation systems dependent on sewers, water, and long planning horizons—are often not viable.

Waterborne diseases remain a leading cause of morbidity and mortality. As noted in recent research, waterborne diseases claim over a million lives year-round, with diarrhea being a leading cause of death for children under five in the Global South. An astonishing 2.2 billion people lack access to safe drinking water, and in the Global South, even tap water can be unreliable and unsafe. These challenges are compounded by climate change: "Floods, droughts, and shifting water sources are amplifying existing stresses".

➢ *The Promise of AI for WASH*

AI offers several potential advantages for addressing WASH challenges in resource-constrained settings. First, AI can enhance predictive capabilities, enabling early warning of contamination events and informing proactive interventions. Second, AI can improve the efficiency and scalability of monitoring through automated analysis of remote sensing data, reducing reliance on costly and logistically challenging field sampling. Third, AI can support decision-making by synthesizing complex, multi-dimensional data to identify optimal resource allocation strategies. Fourth, AI-powered tools can democratize access to WASH knowledge and technical support, reaching communities through familiar platforms like mobile phones.

As Izah and Ogwu (2025) articulate, "Predictive modeling emerges as a pivotal tool in addressing these challenges, offering data-driven insights to anticipate contamination events and optimize mitigation strategies". The integration of advanced technologies such as remote sensing and AI into predictive frameworks has the potential

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to improve accuracy and scalability in resource-constrained settings.

- *The Data-Scarcity Paradox*

A fundamental challenge for AI applications in SSA is the tension between the data-hungry nature of most AI algorithms and the data-scarce reality of the region. As noted in a recent review, "persistent challenges include data scarcity in developing regions (only 12% of Sub-Saharan African monitoring stations provide real-time data)". This data scarcity is not merely a technical limitation but reflects deeper systemic issues: inadequate monitoring infrastructure, limited funding for data collection, and fragmented data systems.

However, recent advances offer pathways to address this paradox. The development of data-efficient and explainable ML frameworks for predicting microbial contamination risk using low-cost physicochemical parameters demonstrates that meaningful predictions can be achieved with limited data. Similarly, the application of self-supervised learning to satellite imagery enables infrastructure assessment without extensive ground-truth data. These approaches suggest that the data-scarcity challenge, while significant, is not insurmountable.

IV. AI APPLICATIONS IN WASH: KEY DOMAINS

- *Water Quality Monitoring and Prediction*

Water quality monitoring is the most extensively developed domain of AI application in WASH across SSA. Traditional monitoring methods involving on-site sample collection and laboratory analysis are time-consuming, expensive, and impractical in remote or hard-to-access settlements. AI-driven approaches offer the potential for real-time, remote, and cost-effective monitoring.

- Machine Learning for Predictive Modeling: A substantial body of research has demonstrated the efficacy of ML models for predicting water quality parameters and contamination events. Izah and Ogwu (2025) conducted a comprehensive review highlighting the application of predictive modeling techniques including machine learning, hydrological simulations, and quantitative microbial risk assessment to identify contamination hotspots, forecast pathogen dynamics, and inform water resource allocation in the Global South. Case studies from SSA and South Asia demonstrated the efficacy of predictive modeling tools in guiding public health actions, from prioritizing water treatment efforts to implementing early-warning systems during extreme weather events.
- Earth Observation and Remote Sensing: The integration of Earth observation (EO) data with machine learning has emerged as a particularly promising approach for water quality monitoring across the region. A 2025 study by Mant et al. explored the potential of EO data to monitor bacterial contamination in surface waters in West Africa, investigating the relationship between E. coli concentrations and various water quality parameters. Using eight machine learning models, the study demonstrated that ensemble tree-based models provided the best predictive performance, and that EO variables alone could achieve R^2 values of approximately 0.7. This approach enables remote monitoring of microbial water quality, significantly reducing the need for field sampling.
- IoT and Citizen Science Integration: The convergence of Internet of Things (IoT) sensors, citizen science, and machine learning represents an innovative model for real-time water quality monitoring. A 2025 study developed a decentralized IoT and citizen science framework for real-time water quality monitoring in Lagos, Nigeria. The system employed off-the-shelf water quality sensors, a wireless sensor network, and the TUYA platform, with a machine-learning-based soft-sensor validating readings and predicting water potability. Local high school students, trained as citizen scientists, ensured sensor safety and data integrity. This approach demonstrates the potential for community-engaged, AI-powered monitoring in urban informal settlements.
- Hybrid AI Models: Recent research has advanced hybrid AI frameworks for water quality prediction in data-scarce regions. A 2026 study developed a hybrid AI model integrating Long Short-Term Memory (LSTM), Extreme Gradient Boosting (XGBoost), and K-Means clustering for interpretable prediction and clustering of water quality in the Niger Delta. The study addressed the limitations of traditional monitoring methods cost, temporal gaps, and lack of interpretability by combining the strengths of different AI approaches.
- Chlorine Decay Modeling: In the context of drinking water treatment, AI has been applied to model chlorine demand and decay in aging distribution systems. A 2026 study developed an AI-driven ML model based on the parallel-first-order chlorine decay model to predict chlorine consumption and decay within an aging drinking water distribution network in South Africa. The ML model successfully determined the optimal neural network configuration to fit experimental data, simplifying the complexity of chlorine decay models. The study found that chlorine demand was linearly dependent on the chlorine dose ($R^2 = 0.95$), with the optimum chlorine dose being 6.30 mg/L.
- Smartphone-Based Monitoring: The proliferation of smartphones across SSA has enabled the development of mobile applications for water quality monitoring. A study from South Africa investigated the development of a smartphone application using machine learning and computer vision to perform real-time, automated analysis of water quality test strips. Findings underscored the potential of AI-driven solutions to revolutionize water quality monitoring in South Africa, with system performance exceeding minimum requirements for practical deployment.

- *Sanitation Infrastructure Assessment*

Sanitation infrastructure or the lack thereof represents a critical challenge across SSA, yet reliable data on infrastructure access remains sparse, costly, and delayed. AI

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and remote sensing offer novel approaches to bridge this data gap. Satellite-Based Infrastructure Mapping: A landmark 2026 study by Echchabi et al. developed a scalable remote-sensing framework to estimate piped water and sewage system access at approximately 2.56 km resolution using Sentinel-2 imagery, Afrobarometer survey responses, 30 m population data, and DINO self-supervised Vision Transformer features. The best model achieved AUROC values of 91.54% for piped water and 93.24% for sewage access. Across 50 African countries, population-weighted estimates strongly aligned with WHO/UNICEF JMP statistics for piped water ($R^2 = 0.92$) and showed meaningful agreement for sewage access ($R^2 = 0.72$). A Nigeria case study across 767 Local Government Areas revealed fine-scale environmental inequality, with the largest no-access burdens reaching 1.155 million people for piped water and 1.452 million for sewage. These findings demonstrate that DINO-based satellite models can complement household surveys with low-cost, spatially detailed evidence for SDG 6 monitoring.

- Deep Learning for Infrastructure Detection: Complementary research has demonstrated the potential of deep learning models to monitor and evaluate piped water and sewage system access from satellite imagery. By utilizing both Landsat and Sentinel datasets with Vision Transformer architectures, the precision and reliability of water and sanitation infrastructure assessments were enhanced. Circular Sanitation Solutions: AI is also being applied to the design and implementation of circular sanitation systems. A transdisciplinary research project in Limpopo, South Africa, and Manica Province, Mozambique, aims to co-create circular sanitation systems and financially viable service delivery models to address poor hygiene, sanitation, and malnutrition. The project employs AI-based hackathons to co-innovate circular sanitation options, recognizing that "off-grid systems, designed to be self-contained and zero-energy, can revolutionize the sanitation sector".

➢ *Waterborne Disease Surveillance and Prediction*

The prediction and surveillance of waterborne diseases represent a critical intersection of WASH and public health, where AI offers substantial potential.

- Weather-Sensitive Disease Prediction: A 2025 study by Lyimo et al. evaluated the potential of machine learning to predict and manage weather-sensitive waterborne diseases in selected Tanzanian districts. The study surveyed 76 environmental health officers (EHOs), finding that while most were moderately familiar with ICT, only 54% had prior exposure to AI/ML concepts, and 64% reported limited AI familiarity. Despite this, the majority recognized AI/ML's potential to improve disease prediction accuracy. Key barriers to ML adoption included inadequate technical infrastructure, data quality issues, and a shortage of expertise. Opportunities identified included utilizing historical disease data, integrating AI with meteorological information, and using satellite imagery for surveillance.
- AI-Supported Social Listening: The World Health Organization's Africa Regional Office has explored AI-supported social listening for cholera response. A 2026 webinar demonstrated how AI is used to track infodemic trends across countries, identify key drivers such as trust, water and sanitation concerns, and vaccine perceptions, and inform evidence-based risk communication and community engagement strategies. This approach recognizes that effective disease response requires not only prediction but also understanding of community perceptions and concerns.
- Predictive Modeling for Public Health Protection: The broader application of predictive modeling to microbial water contamination has been extensively reviewed by Izah and Ogwu (2025), who emphasized the importance of region-specific modeling approaches and the integration of environmental, socioeconomic, and climatic factors. The review highlighted that "predictive models enable targeted actions to improve water safety and lower the prevalence of waterborne diseases by combining environmental, socioeconomic, and climatic factors".

➢ *Citizen Science and Community Engagement*

The democratization of WASH monitoring and knowledge through AI-powered citizen science represents an emerging and promising domain. The miniSASS Platform: The mini stream assessment scoring system (miniSASS) was developed in South Africa as a citizen science biomonitoring tool for assessing water quality and health of stream and river systems. The miniSASS app digitizes and streamlines ground surveys for data collection, monitors data quality, and incorporates machine learning to auto-verify readings. An AI-powered version of the app enables automatic, real-time identification of macroinvertebrates, significantly lowering the barrier to participation.

- WASHtsApp Chatbot: The WASHtsApp project has developed a WhatsApp-based chatbot designed to educate rural African communities on clean water access, sanitation, and hygiene principles. Leveraging a Retrieval-Augmented Generation (RAG) approach, the chatbot responds to questions and provides guidance on WASH-related issues. The current study aims to develop a prototype to serve rural Ugandan areas with advice regarding WASH principles. This approach recognizes the ubiquity of WhatsApp across Africa and the potential for AI-powered conversational agents to disseminate WASH knowledge at scale.
- Community Science in East Africa: A 2025 initiative brought together traditional monitoring, community science, and AI approaches to improve understanding of water quality and the spatial distribution of geogenic contaminants in East Africa. This integrated approach recognizes that AI cannot replace local knowledge but can complement and enhance community-based monitoring efforts.
- Digital Twin Integration: A 2026 capacity-building workshop focused on integrating citizen-generated water quality data into an AI-driven Digital Twin for water

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management in the Limpopo River Basin. The workshop addressed critical issues of incentivization and digital inclusivity, recognizing that effective AI-WASH solutions must be co-designed with communities.

- *Decision Support and Knowledge Management*

Beyond monitoring and prediction, AI is being applied to support WASH decision-making and knowledge management.

- WASH AI Knowledge Platform: Baobab Tech has developed WASH AI, a platform designed to make sector knowledge more accessible through artificial intelligence. The platform aims to support professionals working in governments, NGOs, and community organizations by providing AI-powered knowledge tools, technical support, and learning resources across 20+ languages. As one observer noted, "AI-powered systems have the potential to optimise distribution networks, predict service disruptions, and improve the efficiency of sanitation services".
- AI Learning Companions: The WASH Systems Academy, serving over 8,000 registered learners, has developed an AI Learning Companion to support self-directed learning and connect users with relevant sector knowledge. This application demonstrates the potential of AI to enhance capacity building and professional development in the WASH sector.
- Predictive Analytics for Resource Allocation: AI-powered predictive analytics can inform water resource allocation, particularly in water-stressed regions. A 2025 review investigated the application of AI, deep learning, and IoT in water resource management, focusing on distribution optimization, demand prediction, and water quality enhancement. These applications are particularly relevant for SSA, where water scarcity and infrastructure deficits create pressing needs for efficient resource allocation.

- *Case Studies from Sub-Saharan Africa*

- *Nigeria: IoT-Citizen Science Integration in Lagos*

The Lagos IoT-citizen science framework represents a pioneering model for community-engaged water quality monitoring in urban informal settlements. The system's decentralized architecture employing off-the-shelf sensors, a wireless sensor network, and machine learning for potability prediction addresses the impracticality of traditional monitoring methods in hard-to-access settlements. The engagement of local high school students as citizen scientists not only ensures sensor safety and data integrity but also builds local capacity and ownership. Contamination events sent via digital channels enable timely interventions, offering cost-effective solutions.

- *Tanzania: Machine Learning for Waterborne Disease Prediction*

The Tanzanian study on weather-sensitive waterborne diseases provides valuable insights into the barriers and opportunities for AI adoption in public health. The finding that only 54% of EHOs had prior exposure to AI/ML concepts highlights the critical need for capacity building. However, the recognition among EHOs of AI's potential to improve disease prediction accuracy suggests readiness for adoption, provided that infrastructural and capacity barriers are addressed.

- *South Africa: AI for Chlorine Decay Modeling*

The South African study on chlorine demand and decay modeling demonstrates the application of AI to a specific operational challenge in drinking water treatment. The finding that chlorine demand was linearly dependent on chlorine dose ($R^2 = 0.95$), with an optimum dose of 6.30 mg/L, provides actionable insights for water utilities. The study's recommendation that ML models be coupled with solute transport models to simulate the effect of distance highlights the importance of integrating AI with domain-specific physical models.

- *Kenya: Remote Sensing of Reservoir Turbidity*

Research on predicting turbidity dynamics in small reservoirs in central Kenya using remote sensing and machine learning demonstrates the application of AI to water quality monitoring in data-scarce contexts. The use of Sentinel-2 data from 2017 to 2023, combined with primary and secondary Earth observation data, enabled the prediction of turbidity outcomes, providing a model that can be replicated across similar contexts.

- *West Africa: Earth Observation for Bacterial Contamination*

The West African study on monitoring bacterial contamination using Earth observation and machine learning represents a significant advance in remote water quality monitoring. The finding that ensemble tree-based models maintained good performance ($R^2 \approx 0.7$) using only EO variables demonstrates the feasibility of remote monitoring. The identification of suspended particulate matter and rainfall as the strongest predictive variables provides insights into the environmental drivers of contamination.

- *Challenges and Barriers to AI Adoption*

- *Data Scarcity and Quality*

Data scarcity remains the most fundamental barrier to AI adoption in WASH across SSA. As noted in recent reviews, only 12% of Sub-Saharan African monitoring stations provide real-time data. This scarcity reflects inadequate monitoring infrastructure, limited funding, and fragmented data systems. Even where data exist, quality issuesincluding incompleteness, inconsistency, and lack of standardization pose significant challenges for AI model development and validation.

- *Infrastructure Deficits*

The infrastructural deficits that characterize WASH in SSA also constrain AI adoption. Inadequate electricity supply, limited internet connectivity, and lack of computing infrastructure hinder the deployment and maintenance of AI systems. As noted in the Tanzanian study, "inadequate technical infrastructure" was identified as a key barrier to ML adoption. Similarly, water utilities face significant

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financing challenges, with a $5 billion funding gap identified in Kenya alone to achieve universal access by 2030. 6.3 Technical Capacity and Human Resources.

The shortage of AI expertise across SSA represents a critical constraint. The Tanzanian study found that 64% of EHOs reported limited AI familiarity. This capacity gap extends beyond frontline health workers to include water utility staff, policymakers, and other WASH professionals. As one observer noted, "How do smaller organizations get started without deep technical capacity?". Building local AI capacity requires investment in education and training, as well as the development of appropriate tools and platforms that lower the technical barrier to entry.

➢ *Ethical and Governance Concerns*

The ethical dimensions of AI adoption in WASH have received increasing attention. As noted in a recent WASH professional gathering, questions around "data governance, algorithmic accountability, and responsible implementation" were significant areas of concern. The phenomenon of "AI washing" where companies market basic automation tools as AI without delivering real technological substance or oversight has been identified as a risk in the African context. Ensuring that AI solutions are transparent, accountable, and aligned with community needs requires robust governance frameworks.

➢ *Contextual Appropriateness and Local Adaptation*

The importance of local adaptation and contextual appropriateness has been emphasized across the literature. As noted in a WaterAid report, "what stood out most was the emphasis on local adaptation... and responsive to the realities of African communities". AI solutions developed in and for high-resource contexts may not transfer effectively to SSA without substantial adaptation. The development of region-specific modeling approaches, as emphasized by Izah and Ogwu (2025), is essential.

➢ *Sustainability and Scalability*

Many AI-WASH initiatives remain at the pilot or research stage, with limited evidence of sustainability and scalability. The challenge of moving from proof-of-concept to widespread operational deployment requires attention to business models, institutional embedding, and long-term maintenance. As the Water Project's experience with ShockCalc demonstrates, even successful AI tools require ongoing refinement and support.

➢ *Opportunities and Future Directions*

- *Emerging Solutions for Data Scarcity*

Recent advances offer promising pathways to address the data-scarcity challenge. Federated learning, which enables model training across distributed data sources without centralized data collection, has shown potential in pan-African contexts, with studies reporting 35% accuracy improvement in E. coli prediction. Explainable AI approaches, such as SHAP-guided nitrate models, address concerns about "black-box" systems and build trust among practitioners. Data-efficient ML frameworks that achieve meaningful predictions with limited data are under active development.

- *Leveraging Mobile and Digital Platforms*

The high penetration of mobile phones across SSA offers a unique opportunity for AI-powered WASH solutions. From WhatsApp-based chatbots to smartphone applications for water quality monitoring, mobile platforms provide a scalable channel for reaching communities. As one observer noted, "Real-time tools, much like mobile payments that revolutionised finance in Africa, can unlock new efficiencies in WASH services".

➢ *Integration with Existing Systems*

The integration of AI with existing WASH monitoring and management systems offers a pragmatic pathway to adoption. Rather than replacing conventional approaches, AI can complement and enhance them. For example, AI-powered anomaly detection can flag potential contamination events for follow-up by conventional sampling. AI can also enhance the efficiency of existing infrastructure by optimizing chlorine dosing or predicting maintenance needs.

➢ *Capacity Building and Knowledge Transfer*

Building local AI capacity is essential for sustainable adoption. This includes not only technical training but also the development of appropriate tools and platforms that lower the barrier to entry. Initiatives like the WASH Systems Academy's AI Learning Companion and WASH AI's knowledge platform demonstrate the potential for AI to support professional development and knowledge sharing. Collaborative, transdisciplinary approaches such as the circular sanitation project in South Africa and Mozambique can build local expertise while developing context-appropriate solutions.

➢ *Policy and Governance Frameworks*

The development of appropriate policy and governance frameworks is critical for responsible AI adoption in WASH. This includes data governance frameworks that protect privacy and ensure data quality, algorithmic accountability mechanisms that enable scrutiny and redress, and ethical guidelines that ensure AI solutions are aligned with community needs and values. As experts have warned, without adequate governance, "AI could turn a technological breakthrough into a national vulnerability".

➢ *Climate Adaptation and Resilience*

Climate change is intensifying WASH challenges across SSA, with floods, droughts, and shifting water sources amplifying existing stresses. AI has a critical role to play in climate adaptation, from predicting weather-sensitive waterborne diseases to optimizing water resource allocation under changing conditions. The development of early-warning systems for contamination events during extreme weather is a particularly important application.

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V. DISCUSSION

➢ *Synthesis of Findings*

This review has demonstrated that AI applications in WASH across Sub-Saharan Africa span a diverse range of domains from water quality monitoring and prediction to sanitation infrastructure assessment, disease surveillance, citizen science, and decision support. Across these domains, AI has shown substantial promise in research settings, with studies demonstrating improved predictive accuracy, scalable monitoring through remote sensing, and enhanced community participation through AI-powered tools. However, the translation of this promise to widespread operational deployment remains constrained by systemic barriers. Data scarcity, infrastructural deficits, limited technical capacity, and ethical concerns collectively limit the reach and impact of AI-WASH initiatives. The data-scarcity paradox where the data-hungry nature of most AI algorithms confronts the data-scarce reality of the region is particularly fundamental.

The case studies reviewed reveal a pattern of successful pilot demonstrations that have yet to achieve sustainable scaling. The Lagos IoT-citizen science framework, the West African Earth observation study, and the Tanzanian disease prediction study all demonstrate technical feasibility and potential impact, yet questions of long-term sustainability, institutional embedding, and scalability remain.

➢ *Comparison with Global Trends*

The AI-WASH landscape in SSA reflects broader global trends while also exhibiting distinctive characteristics. Globally, AI is being applied to water quality monitoring, infrastructure management, and disease prediction. However, the SSA context is distinguished by the severity of data scarcity, the prominence of mobile-first solutions, and the emphasis on community engagement and citizen science. The high penetration of mobile phones across the region has enabled innovations like WASHtsApp and smartphone-based water quality monitoring that may be less relevant in higher-income contexts.

➢ *Limitations of the Review*

Several limitations of this review should be acknowledged. First, the evidence base is uneven across domains and countries, with some applications (water quality monitoring) better represented than others (sanitation management). Second, much of the literature reports on pilot studies rather than operational deployments, limiting insights into long-term sustainability. Third, the rapid pace of AI development means that some findings may become outdated quickly. Fourth, grey literature and non-English publications may have been underrepresented.

➢ *Implications for Policy and Practice*

The findings of this review have several implications for policy and practice: Investment in Data Infrastructure: Addressing data scarcity requires investment in monitoring infrastructure, data systems, and open data platforms. The development of data-efficient AI approaches can help, but cannot substitute for adequate data collection. Capacity Building: Building local AI capacity through education, training, and the development of accessible tools is essential. This includes not only technical skills but also the ability to critically evaluate and govern AI systems.

- Context-Appropriate Design: AI solutions must be designed with local contexts in mind, recognizing the infrastructural, cultural, and institutional realities of SSA. Co-design with communities and end-users is critical. Integration and Interoperability: AI solutions should be designed to integrate with existing WASH systems and data sources, rather than operating in isolation. Ethical Governance: Robust governance frameworks are needed to ensure that AI solutions are transparent, accountable, and aligned with community values.

VI. CONCLUSION

Artificial intelligence holds significant promise for addressing the persistent WASH challenges facing Sub-Saharan Africa. Across domains including water quality monitoring, sanitation infrastructure assessment, disease surveillance, citizen science, and decision support, AI-driven approaches have demonstrated technical feasibility and potential impact. The integration of remote sensing with machine learning enables scalable monitoring of water quality and sanitation infrastructure; predictive modeling supports early warning of contamination events and waterborne disease outbreaks; and AI-powered mobile tools democratize access to WASH knowledge and community participation.

However, the translation of this promise to widespread operational deployment faces substantial barriers. Data scarcity, infrastructural deficits, limited technical capacity, and ethical concerns collectively constrain the reach and impact of AI-WASH initiatives. Addressing these barriers requires sustained investment in data infrastructure, capacity building, context-appropriate design, and ethical governance.

As the WASH sector grapples with the accelerating impacts of climate change, rapid urbanization, and persistent inequalities, the imperative for innovative solutions has never been greater. AI is not a panacea it cannot substitute for the fundamental investments in infrastructure and institutions that are essential for universal WASH access. However, when deployed responsibly and in alignment with community needs, AI can be a powerful tool for enhancing the efficiency, equity, and resilience of WASH services across Sub-Saharan Africa. The path forward requires collaboration across disciplines and sectors between data scientists and WASH practitioners, between technologists and communities, between researchers and policymakers. It requires a commitment to building local capacity and ownership, ensuring that AI serves African communities rather than being imposed upon them. And it requires a recognition that the ultimate measure of success is not technical performance but improved health, dignity, and

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well-being for the millions across Sub-Saharan Africa who still lack access to safe water, adequate sanitation, and proper hygiene.

➢ *Consent to Participate Declaration*

Declarations for the Review Paper Consent to Participate Declaration Not applicable. This review paper does not involve primary data collection from human participants, clinical trials, or studies requiring informed consent. All data presented in this review are derived from previously published peer-reviewed literature, conference proceedings, and institutional reports that have already obtained appropriate ethical approvals and participant consents where applicable.

- *Ethics Declaration:*

The authors declare that this review paper adheres to the highest standards of research ethics and scholarly integrity. This study:

Involves no direct human or animal subjects, clinical interventions, or experimental procedures requiring institutional ethics committee approval.

Has been conducted in accordance with established guidelines for systematic literature reviews and scholarly synthesis.

Ensures proper attribution and citation of all sources, with no instances of plagiarism, data fabrication, or data falsification.

Maintains transparency in methodology, including clear articulation of search strategies, inclusion and exclusion criteria, and analytical approaches.

Acknowledges the limitations of the evidence base, including potential publication bias and the uneven distribution of research across geographic regions and WASH domains.

Respects the intellectual property rights of all cited authors and publications.

Presents a balanced and objective synthesis of the literature, acknowledging both the opportunities and limitations of AI applications in WASH contexts.

The authors affirm that no ethical conflicts arose during the conduct of this review, and all research practices comply with the ethical standards of the Federal University of Environment and Technology, Ogoni, and prevailing international norms for academic research integrity.

- *Data Availability Declaration:*

The data supporting the findings of this review are derived entirely from publicly available sources, including: Peer-reviewed publications indexed in Scopus, Web of Science, PubMed, Google Scholar, and arXiv, as detailed in the reference list.

Institutional reports and gray literature from organizations including WHO/UNICEF Joint Monitoring Programme, WaterAid, FAO, Belmont Forum, and other international bodies, all of which are publicly accessible through their respective institutional repositories. Open-access datasets referenced in the included studies, which are available through the original publications and their supplementary materials.

All sources cited in this review are listed in the references section and can be accessed through their respective publishers, institutional repositories, or digital object identifiers (DOIs) where available. No primary data were collected or generated for this review. The search strategy, inclusion and exclusion criteria, and analytical framework are fully described in the methodology section to ensure reproducibility.

The authors confirm that they have no unpublished datasets associated with this review. Any aggregated data or summary statistics presented in this paper can be derived from the cited sources and are available upon reasonable request to the corresponding author.

- *Author Contribution Declaration:*

✓ Bealo Deebari Brownson (a): Conceptualization, project administration, supervision, writing—original draft preparation, writing—review and editing, methodology development, formal analysis, investigation, validation, visualization, funding acquisition (where applicable), and resources. Dr. Brownson led the overall design of the review, guided the theoretical framework, and contributed substantially to the analysis of AI applications in water quality monitoring and prediction.
✓ Ayakpo Akpi (b): Methodology development, formal analysis, investigation, data curation, writing—original draft preparation, writing—review and editing, and visualization. Dr. Akpi was primarily responsible for the literature search strategy, data extraction, and synthesis of evidence related to sanitation infrastructure assessment and waterborne disease surveillance.
✓ Bakpo Dumka John (c): Methodology development, investigation, writing original draft preparation, writing—review and editing, visualization, and resources. Mr. John contributed significantly to the analysis of citizen science applications, community engagement approaches, and the synthesis of case studies from across Sub-Saharan Africa.
✓ Bealo Lekie Meedubari (d): Investigation, data curation, writing original draft preparation, writing—review and editing, validation, and visualization. Ms. Meedubari contributed to the analysis of decision support systems, the identification of challenges and barriers, and the development of the framework for responsible AI integration.
✓ All authors have contributed to the critical revision of the manuscript for important intellectual content, have approved the final version for submission, and agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part

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of the work are appropriately investigated and resolved. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content.

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- ✓ No financial conflicts: The authors have not received any financial support, grants, honoraria, consulting fees, or other remuneration from any organization, company, or individual that could benefit financially from the findings of this review.
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- ✓ No intellectual property conflicts: The authors have no patents, patent applications, or other intellectual property rights related to the technologies or approaches discussed in this review.
- ✓ No editorial or peer review influences: The review process was conducted independently and without any external pressures or influences that could bias the findings.

The authors affirm that the review presents a balanced and objective synthesis of the available evidence, with no attempt to promote any particular technology, product, service, or organization. All interpretations and conclusions are based solely on the scientific literature and the authors' professional expertise. Should any competing interests arise after publication, the authors commit to notifying the journal promptly and taking appropriate corrective action.

REFERENCES

[1]. 12-Hour downpour submerges Lagos roads, homes, businesses as Sanwo-Olu orders dredging of 28 drainage channels. (2026, July 1). Newswatch.

[2]. Accra floods trigger transport breakdown as observer says Transport Ministry "doesn't care" for stranded commuters. (2026, June 30). The High Street Journal.

[3]. A hybrid AI model integrating LSTM, XGBoost, and K-means for interpretable prediction and clustering of water quality in data-scarce regions. (2026). Springer.

[4]. A network of citizen scientists to protect freshwater resources in southern Africa. (2025, September 18). International Water Management Institute. https://www.iwmi.org

[5]. A smart IoT cum citizen science framework for real-time remote water quality monitoring and assessment. (2025). Discover Water, 5, 108. https://doi.org/10.1007/s43832-025-00299-7[reference:132]

[6]. A systematic literature review on transit-based evacuation planning in emergency logistics management: Optimisation and modelling approaches. (2024). Buildings, 14(1).

[7]. Antibiotic removal in South African water using artificial neural networks and adaptive neuro-fuzzy inference system models: A review. (2025). South African Journal of Chemical Engineering.

[8]. Artificial intelligence for optimal water resource management: A literature review. (2025). MDPI.

[9]. Assessing cyanobacteria in a small reservoir using unmanned aerial vehicle systems (UAVs): A case study of High Flight Farm Dam. (2025). FAO.

[10]. Assessing the potential for application of machine learning in predicting weather-sensitive waterborne diseases in selected districts of Tanzania. (2025). Frontiers in Artificial Intelligence, 8, 1597727. https://doi.org/10.3389/frai.2025.1597727[reference:135]

[11]. Beijing evacuates over 100,000 residents, conducts reservoir discharges amid Typhoon Bavi's flood threat. (2026, July 12). Bastille Post.

[12]. Bridging the gap: A review of machine learning in water quality control. (2025). TH Owl.

[13]. Capacity-building workshop Part 2: AI-driven digital twin for water management for the Limpopo River Basin and inclusive integration with citizen science. (2026, March 17). FAO.

[14]. Chennai suburban riders push for frequent MRTS. (2026, May 28). Urban Acres.

[15]. Comparison of multiple linear regression and artificial neural network models in retrieving water quality parameters using remotely sensed data: Lake Victoria (Tanzanian) water. (2025). FAO.

[16]. A data-efficient and explainable machine learning framework for predicting microbial contamination risk in groundwater of resource-constrained regions. (2026). EJASET.

[17]. Echchabi, O., et al. (2026). Monitoring access to piped water and sanitation infrastructure in Africa at disaggregated scales using satellite imagery and self-supervised learning. arXiv:2411.19093.

[18]. Echchabi, O., et al. (2026). Seeing SDG 6 from space: Local-scale monitoring of piped water and sewage system access across Africa using satellite imagery and self-supervised learning. arXiv:2411.19093.

[19]. Experts warn against unregulated AI dispensation in Nigeria. (2025, June 4). New National Star.

[20]. Groundwater vulnerability under climate change: A machine learning framework. (2025). Earth Systems and Environment.

[21]. Izah, S. C., & Ogwu, M. C. (2025). Modeling solutions for microbial water contamination in the

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1337

global south for public health protection. Frontiers in Microbiology, 16, 1504829. https://doi.org/10.3389/fmicb.2025.1504829[reference:144][reference:145].
[22]. Leveraging remote sensing and machine learning for enhanced water quality monitoring for African Lakes. (2025). IWRA World Water Congress 2025 Proceedings.
[23]. Lyimo, N. N., et al. (2025). Assessing the potential for application of machine learning in predicting weather-sensitive waterborne diseases in selected districts of Tanzania. Frontiers in Artificial Intelligence, 8, 1597727.
[24]. Mant, M.-A., Robert, E., Nikiema, H., Boubacar-Moussa, M., Abdourhamane-Toure, A., et al. (2025). Monitoring bacterial contamination of West African surface waters using Earth observation data and machine learning methods. Environmental Advances, 22, 100678. https://doi.org/10.1016/j.envadv.2025.100678[reference:148].
[25]. Nigeria's AI ambitions face risk without governance and security, say experts. (2025, June 3). Nairametrics.
[26]. Predicting turbidity dynamics in small reservoirs in central Kenya using remote sensing and machine learning. (2025). Space4Water.
[27]. Public transit evacuation planning for underserved populations: A systematic literature review. (n.d.).
[28]. Remote sensing with machine learning for multi-decadal surface water monitoring in Ethiopia. (2025). OUCI.
[29]. A review of advanced machine learning and deep learning technologies for water quality management. (2026). Discover Applied Sciences.
[30]. Safety-oriented facility design and operation management for transportation hub station. (2026). Elsevier.
[31]. Temporal modeling of surface water bacteriological quality in West Africa using remote sensing and machine learning methods. (2025). EGU.
[32]. The ability of transit to play an effective role in an emergency evacuation. (n.d.). U.S. Department of Transportation.
[33]. The development of a smartphone application for water monitoring in South Africa using machine learning techniques. (2025). Wits University.
[34]. Transdisciplinary research to co-design, with end users, a circular sanitation solution (C2S) combining local knowledge, international innovation and artificial intelligence in Limpopo, South Africa, and Manica Province, Mozambique. (2025). Belmont Forum.
[35]. Unveiling the chlorine demand and decay in aged drinking water supply systems: Complementing experimental results with modelling and predictive artificial intelligence. (2026). ScienceDirect.
[36]. Urban lifeline resilience under compound hazards: A review on the cascading failures and systemic risk. (2026). ScienceOpen.
[37]. WASHtsApp—A RAG-powered WhatsApp chatbot for supporting rural African clean water access, sanitation and hygiene. (2024). arXiv.
[38]. Water quality in East Africa: Bringing together traditional monitoring, community science and artificial intelligence approaches. (2025). ADS.
[39]. What happened when over 200 WASH professionals showed up to talk about AI. (2026, May 6). The Water Project.
[40]. Why Mumbai's Churchgate–Virar, CSMT–Kalyan routes are being considered for underground shift. (2026, April 19). Times of India.
[41]. WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene. (2025). Progress on household drinking water, sanitation and hygiene 2000–2024