Reconnoitering the Environmental impact of WASH programming and Eco-Innovation in Mozambique: Empirical evidence from Cabo Delgado, province in Northern Mozambique

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Abstract

This study examines the environmental impacts and eco-innovation implications of emergency Water, Sanitation, and Hygiene (WASH) interventions in conflict-affected settings, focusing on Cabo Delgado Province in northern Mozambique. While such interventions are critical for disease prevention and service restoration, their cumulative environmental effects in fragile ecosystems remain underexplored. A mixed-methods approach was employed to assess impacts on groundwater resources, sanitation-related contamination, forest ecosystems, energy use, and solid waste generation. Data were collected through environmental field assessments, surveys, and interviews with humanitarian practitioners, government officials, and community members, focus group discussions with displaced populations, and document analysis. Fieldwork across five districts enabled comparative analysis across varied ecological and displacement contexts. Findings show that, despite improving access to safe water and sanitation, emergency WASH interventions generated environmental pressures. Intensive groundwater abstraction reduced borehole yields, poorly sited latrines increased contamination risks, and plastic-based hygiene kits contributed to persistent waste. Deforestation linked to fuel wood use and reliance on diesel-powered water trucking further exacerbated environmental stress. The study concludes that environmental outcomes are shaped by technological and governance factors and recommends integrating environmental safeguards and eco-innovative solutions to enhance sustainability and resilience. It recommends integrating environmental safeguards, hydrogeological assessments, and eco-innovative solutions such as solar-powered systems, community-led sanitation, and waste-reduction strategies into humanitarian WASH programming to enhance environmental sustainability and resilience in crisis-affected settings in Mozambique.

Keywords: *Environmental Impacts; Political Ecology; Conflict- Eco-Innovation; Humanitarian Governance*

Introduction

This study examines the environmental impacts and eco-innovation potential of emergency Water, Sanitation, and Hygiene (WASH) interventions in conflict-affected settings in Mozambique. Emergency WASH is a critical component of humanitarian response, safeguarding public health, human dignity, and survival. In contexts marked by armed conflict, population displacement, and climatic shocks, WASH programmes are deployed rapidly and at scale to prevent disease outbreaks and reduce mortality (Ehap, 2023). However, the urgency of such interventions raises significant concerns regarding their environmental consequences, particularly in ecologically fragile and institutionally constrained contexts.

Drawing on more than fifteen years of professional humanitarian experience, the study observes that life-saving WASH activities including water trucking, borehole drilling, temporary sanitation facilities, and mass hygiene kit distribution can generate substantial environmental pressures (Amanda et al., 2021). These pressures manifest as groundwater over-extraction, deforestation, plastic waste accumulation, soil

contamination, and increased carbon emissions. Yet, environmental considerations are rarely prioritised within emergency planning frameworks.

Conceptually, the study examines the relationships between WASH operational practices such as rapid infrastructure deployment, energy use, material inputs, and service delivery modalities and their environmental outcomes, including ecosystem degradation, resource depletion, and waste generation (Ahmia, 2024). It further explores eco-innovation as a pathway to mitigate environmental harm while maintaining the life-saving effectiveness of emergency interventions. Central to the analysis is the tension between delivering urgent humanitarian assistance and protecting environmental systems that underpin long-term human and ecological resilience.

Despite global guidance, including the Sphere Handbook and Global WASH Cluster standards (Sphere, 2018; Global WASH Cluster, 2021), environmental sustainability remains inconsistently integrated into emergency WASH programming. Interventions are frequently implemented without comprehensive Environmental Impact Assessments (EIAs), and sustainability planning is often limited to short-term solutions that deteriorate once external support ceases (Yates, 2023; UNICEF, 2024). Operational pressures such as reliance on fossil fuel-powered pumps, single-use plastic hygiene kits, and pit latrines without adequate waste treatment prioritise rapid service delivery but often impose lasting environmental costs, including groundwater depletion, surface water pollution, deforestation, and solid waste accumulation (Sanderson, 2020; Haverkort et al., 2019; Walden et al., 2022; UNEP/OCHA, 2020). Limited community participation further reduces the contextual appropriateness and environmental compatibility of interventions.

The study also identifies a persistent gap between policy commitments and operational practice. While sustainability and eco-innovation are increasingly emphasised in humanitarian discourse particularly in response to climate change and protracted displacement their practical application remains inconsistent, poorly documented, and constrained by limited monitoring mechanisms (Oxfam, 2023; IRC, 2022; UNHCR, 2021; Global Humanitarian Overview, 2023; Sphere, 2022). These challenges are particularly pronounced in Cabo Delgado Province, where armed conflict since 2017 and recurrent climate shocks have produced large-scale displacement, heightened reliance on emergency WASH, and increased environmental stress, including aquifer depletion, sanitation contamination, and public health risks (Ballard Brief, 2020; UNICEF, 2022; UNDP, 2022; UNICEF, 2024).

This study addresses these critical knowledge gaps by empirically examining the environmental impacts of emergency WASH in Cabo Delgado and exploring eco-innovative pathways for integrating environmental sustainability into humanitarian response. By combining operational analysis with ecological considerations, it contributes novel insights on how emergency WASH interventions can balance life-saving objectives with environmental stewardship, offering a transferable framework for conflict-affected and disaster-prone settings.

Methodology

The study adopted a mixed methodological that enabled collection of both quantitative and qualitative data. It also examines the environmental impacts of emergency water, sanitation, and hygiene (WASH) interventions in Cabo Delgado Province, Northern Mozambique. The study is situated within an interpretive research orientation that recognizes environmental outcomes in humanitarian contexts as socially mediated, operationally contingent, and shaped by political, institutional, and ecological interactions rather than as purely technical or value-neutral phenomena.

Research Design

This study adopts a qualitative case study design to investigate the environmental impacts and eco-innovation potential of emergency WASH interventions in Cabo Delgado, Mozambique. As Creswell and Creswell (2020) note, a research design provides the logical framework linking research questions to empirical investigation, guiding decisions on data collection, analysis, and interpretation. Qualitative research is particularly suited to exploring meanings, experiences, and context-specific processes that cannot be reduced to quantitative measures (Makateng & Mokala, 2025). Case study approaches enable in-depth understanding of complex phenomena in real-life contexts, especially when the boundaries between the phenomenon and its context are blurred (Walden et al., 2022).

The study is grounded in an interpretivist research philosophy. Ontologically, it assumes that reality is socially constructed and context-dependent, with environmental impacts of emergency WASH interventions shaped by human actions, institutional arrangements, power relations, and ecological conditions rather than purely technical factors (Makateng & Mokala, 2025). Epistemologically, knowledge is considered subjective and co-constructed through engagement with humanitarian practitioners and affected communities. Participants' experiences were treated as critical sources of insight into how environmental considerations are prioritised, constrained, or negotiated in practice.

Data Collection and Triangulation

Data were generated through multiple qualitative methods, including semi-structured interviews, key informant interviews (KIIs), focus group discussions (FGDs), and document analysis. Interviews captured operational experiences and environmental challenges among humanitarian practitioners and institutional stakeholders. FGDs explored collective perceptions and community-level experiences, while document analysis of operational reports, environmental assessments, and policy frameworks provided triangulation and strengthened the credibility of findings. Using multiple data sources aligns with Inter-Agency Standing Committee guidance, which emphasises context-specific qualitative evidence for understanding environmental risks and opportunities in humanitarian action (IASC, 2023).

Study Area

A thorough understanding of the study area is essential for situating findings within their operational, environmental, and socio-political context (Yin, 2018). Cabo Delgado Province in northern Mozambique was selected due to the convergence of protracted conflict, large-scale emergency WASH interventions, environmental vulnerability, and limited empirical research on the environmental dimensions of humanitarian response.

Cabo Delgado, Mozambique's northernmost province, borders Tanzania to the north and the Indian Ocean to the east, with an estimated population of approximately 2.3 million (UNICEF, 2024). Geographically, the province combines coastal lowlands and inland plateaus, with tropical climate conditions and distinct rainy and dry seasons that influence water availability, groundwater recharge, and sanitation system performance.

Since 2017, armed insurgency has disrupted livelihoods, infrastructure, and public services, displacing over 1.3 million people by 2023 and creating acute humanitarian needs (OCHA, 2023). Rapidly established temporary settlements and host-community expansions often occupy ecologically fragile areas with limited capacity to absorb sustained humanitarian interventions. The province is also politically and environmentally complex due to abundant natural resources, including offshore gas reserves. Political ecology literature emphasises that resource-rich contexts often generate uneven power relations, contested governance, and differentiated access to environmental benefits and burdens, shaping how resources are controlled and degraded (Perreault et al., 2022).

Humanitarian actors, including UNICEF, Médecins Sans Frontières (MSF), and the International Committee of the Red Cross (ICRC), have implemented extensive emergency WASH interventions across districts such as Ancuabe, Montepuez, and Mueda. Activities include borehole drilling, water trucking, hygiene kit distribution, and solar-powered water systems. While these interventions are critical for public health and human dignity, their cumulative environmental impacts on groundwater, waste generation, energy use, and land degradation remain insufficiently examined.

The concentration of sustained emergency WASH operations in conflict-affected, environmentally sensitive, and politically contested setting positions Cabo Delgado as an ideal case for exploring how life-saving humanitarian interventions can generate unintended environmental pressures and how eco-innovative practices can be integrated to enhance sustainability without compromising emergency effectiveness.

Figure 1: Showing map of Cabo Delgado province

Figure 1: Mozambique – Map of Cabo Delgado Province and districts
Source: Google

Contextual Challenges: Conflict, displacement, and climate vulnerability Armed conflict and insecurity

The lengthy armed conflict has not only had a considerable negative effect on the community's ability to recover from hardship, but it has also had a detrimental effect on the infrastructure and the systems that are responsible for providing services throughout the community. This is because the conflict has been going on for a long time. The number of people who have access to basic water, sanitation, and hygiene (WASH) services has decreased as a consequence of armed attacks, which have caused damage to water stations, sanitation facilities, and health centres. This has led to a decrease in the number of people who have access to these necessary services (OCHA, 2021). It is not uncommon for humanitarian organizations to be compelled to cease their operations in regions such as Macomia (MSF, 2024). This is particularly the case when they are subjected to attacks and threats to the safety of their employees.

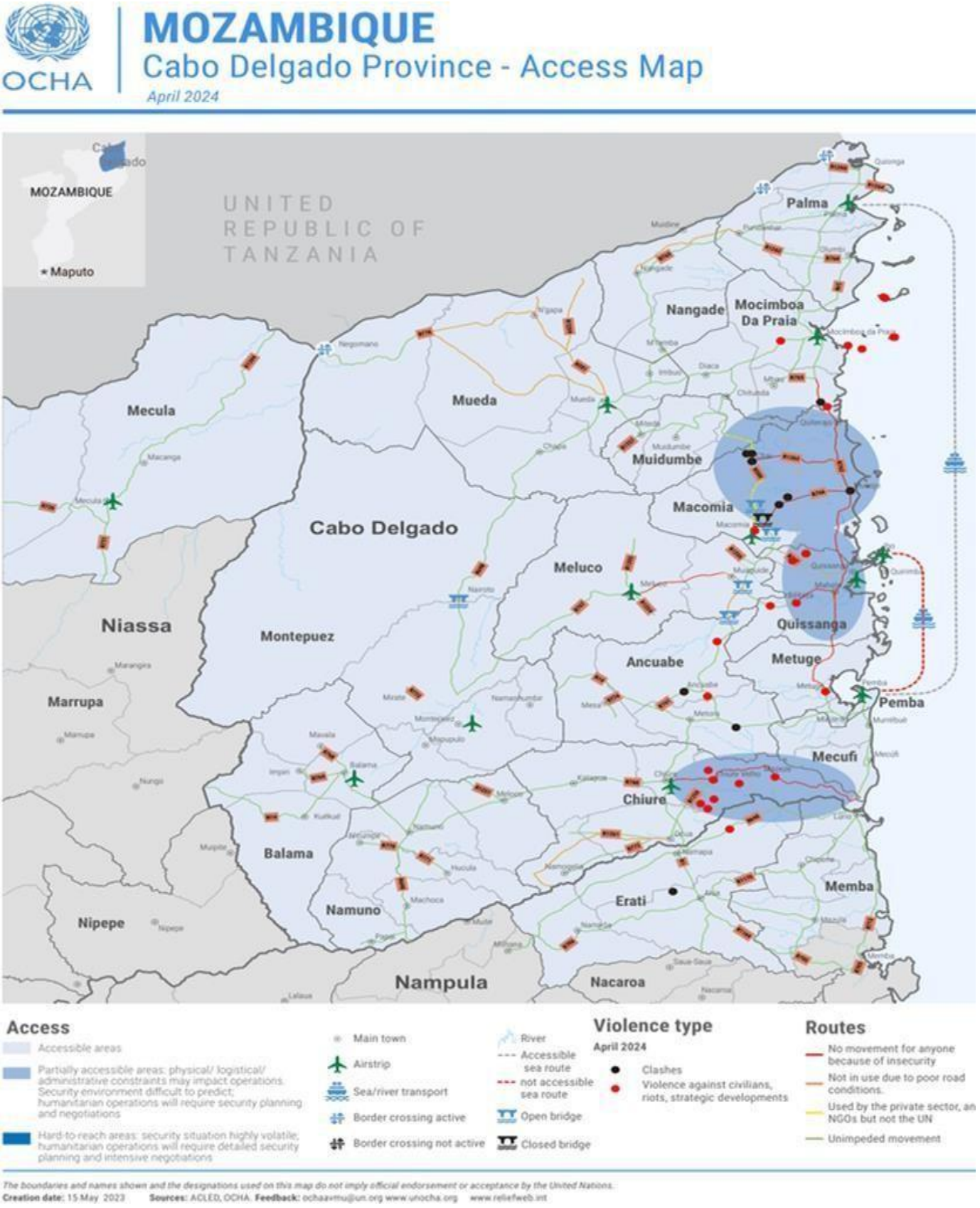

Figure 1: Mozambique – Access map of Cabo Delgado Province

Source: UNOCHA

Data collection methods

This study employed qualitative methods to generate in-depth, context-specific insights into the environmental footprint of emergency WASH programming in Cabo Delgado. Data collection methods were carefully aligned with the research objectives to capture both observable environmental impacts and the lived experiences, institutional dynamics, and decision-making processes shaping WASH implementation (Taherdoost, 2021).

Epistemologically, the study recognizes that understanding how environmental impacts occur—and how eco-innovative practices can be adopted requires engagement with the perspectives of humanitarian practitioners, authorities, and affected communities. Accordingly, semi-structured interviews, key informant interviews (KIIs), focus group discussions (FGDs), stakeholder consultations, and document analysis were employed to explore operational, institutional, and community-level factors influencing emergency WASH. Aligning methods with the study's interpretivist philosophy ensured methodological coherence, analytical depth, and credible assessment of environmental sustainability in complex humanitarian settings.

Mixed Qualitative Data Collection Strategy

A pluralistic qualitative strategy was adopted, drawing on multiple primary and secondary sources. This methodological triangulation enhanced analytical rigor and credibility (Patton, 2015), enabling the study to capture operational practices, governance dynamics, environmental conditions, and community perceptions in an integrated manner.

Interviews

Semi-structured interviews formed the core engagement with UN and NGO programme staff, WASH technical leads, and field-based implementers. Their flexible structure allowed consistency across participants while enabling in-depth exploration of operational challenges, environmental considerations, and opportunities for eco-innovation (DiCicco Bloom & Crabtree, 2006). Interviews addressed topics such as environmental impacts, decision-making processes, operational constraints, and potential sustainability interventions.

Informant Interviews (KIIs)

KIIs were conducted with government officials from provincial and district water and environmental departments, as well as the WASH Cluster Coordinator. These participants offered insights into policy frameworks, inter-agency coordination, and environmental safeguards in emergency WASH. KIIs were particularly suited to examining governance and institutional dimensions, informing strategies for environmentally sustainable and resilient programming (Research Objective Four).

Focus Group Discussions (FGDs)

FGDs engaged community leaders, WASH committee members, volunteers, and residents. This approach captured collective experiences and perceptions, reflecting the social interpretation of environmental impacts in displacement and conflict-affected settings. FGDs explored service delivery, observed environmental changes, local coping strategies, and community-driven mitigation practices, supporting triangulation and identifying locally grounded eco-innovations (Olsson, 2020).

Observation Checklists

Field-based environmental assessments employed structured observation checklists at selected WASH sites to document actual environmental conditions. Drawing on UNEP's NEAT+ guidance (UNEP, 2020), assessments examined groundwater depletion, borehole overuse, deforestation, land degradation, solid waste accumulation, wastewater management, and renewable energy adoption, including solar-powered water systems. This direct observation complemented reported practices with tangible, site-level evidence.

Document Review

Secondary data, including policy documents, operational reports, project evaluations, and environmental audits, were reviewed to situate primary findings within broader institutional, regulatory, and governance contexts (UNEP, 2021; Sphere Association, 2018). Documents analyzed included Mozambique's national water and sanitation policies, UNEP sustainability guidelines, Sphere Standards, and relevant humanitarian operational frameworks. Materials produced between 2020 and 2025 were prioritized to ensure relevance to current humanitarian and environmental conditions in Cabo Delgado (OCHA, 2023; UNEP, 2021).

Reliability and Validity

Ensuring reliable and valid instruments was central to methodological rigor (Taherdoost, 2021; Karnia, 2024). Reliability was achieved through standardized interview guides and observation checklists, while validity was enhanced by methodological triangulation and alignment with research objectives. These measures ensure the trustworthiness, dependability, and credibility of findings.

Qualitative Data Analysis

Data were analyzed thematically, following an iterative process of coding, categorization, and theme development (Miles et al., 2014; Ahmed et al., 2025). Thematic analysis enabled identification of recurring patterns and insights across interviews, FGDs, field observations, and documents, transforming raw data into meaningful evidence on environmental impacts, operational drivers, and eco-innovative practices in emergency WASH programming (Saunders et al., 2012).

Ethical Considerations

Ethical responsibility was integral to the research design, reflecting the heightened vulnerability of participants in conflict-affected settings (Resnik, 2020; Sphere Association, 2018). Informed consent, confidentiality, and contextual sensitivity guided all interactions, ensuring participant dignity and safety while maintaining methodological integrity. Ethics were treated not as a procedural formality but as a core component of research rigor, reflexivity, and responsibility.

Results/Findings

The findings indicated that most of the Respondents reflected a predominantly male WASH workforce, with most participants aged 20–40 and possessing under10 years of experience. Representation spanned NGOs, UN agencies, and government institutions across five districts, ensuring operational, institutional, and community-level perspectives. Two Focus Group Discussions (FGDs) were conducted in Metuge District at the 25 de Junho and Namuapala IDP camps, as shown in Figures 4.1 and 4.2. The 25 de Junho FGD included 14 participants (4 female and 10 male), while the Namuapala session involved 24 participants (14 female, including 3 breastfeeding mothers, and 10 male). Participants from both sites included community leaders, women's representatives, youth volunteers, hygiene promoters, and community members. Although no individual biodata was collected to preserve confidentiality, the discussions provided diverse community perspectives on environmental degradation, hygiene practices, and WASH facility management. These insights grounded the technical findings in lived experience, illustrating how humanitarian WASH interventions shape environmental health, daily coping strategies, and social resilience among displaced populations.

The nature and characteristics of emergency WASH programming in conflict-affected Cabo Delgado, the study reveals that interventions are largely rapid, standardized, and implemented under conditions of insecurity, displacement, and logistical constraint. Across Pemba, Metuge, Montepuez, Mocímboa da Praia, and Quissanga, programming is dominated by short deployment timelines, emergency infrastructure models, and high-pressure service scale-up in IDP-hosting areas.

The findings show that while these interventions are critical for public health protection, their implementation generates unintended environmental pressures. Significant impacts were observed on groundwater abstraction patterns, sanitation system durability, solid waste accumulation, and energy consumption. These environmental effects were particularly pronounced in congested displacement settings where demand intensified pressure on fragile local ecosystems. The analysis identifies specific operational practices that contribute most significantly to the environmental footprint of emergency WASH responses.

The findings also highlight emerging adaptive and eco-innovative practices within the response architecture. Incremental shifts toward solar-powered water systems, improved waste minimization efforts, and community-led facility management models were observed across several districts. Although unevenly implemented, these practices demonstrate growing institutional awareness of environmental sustainability

concerns within humanitarian programming.

Finally, in response to Objective 5, the synthesis of intervention characteristics, environmental impacts, and adaptive innovations provides the foundation for proposing context-specific strategies for integrating environmental sustainability into emergency WASH programming in conflict-affected settings.

Figure 4.5: Abandoned latrine pits and filled pit latrines

Source: *Photo taken during data collection at 25 de Junho IDP resettlement camps, Metuge District, (2025).*

Interpretation of findings

The study indicates that emergency WASH interventions in Cabo Delgado have been pivotal in restoring access to essential water, sanitation, and hygiene services for displacement-affected communities. Across the study districts, activities such as borehole rehabilitation, water trucking, emergency latrine construction, hygiene kit distribution, and hygiene promotion formed the backbone of humanitarian response. Respondents consistently framed these interventions as lifesaving, crucial for preventing disease outbreaks—particularly cholera—in overcrowded IDP settings. Yet, field evidence also highlights that the environmental implications of these interventions were frequently under-recognized during planning and implementation, reflecting a broader humanitarian tendency to prioritize immediacy over ecological safeguards (Sphere, 2018; WHO, 2022).

Institutional perspectives underscore systemic pressure on environmental resources. The Montepuez SDPI Director, in a Key Informant Interview, emphasized the cumulative strain on water, sanitation, and waste management systems due to mass displacement. Similar observations were independently echoed by WASH managers in Pemba and Metuge, where rapid population influxes outpaced the ecological carrying capacity of host communities. The convergence of these perspectives across districts and institutional levels reinforces the structural nature of the challenge.

Environmental impacts were observed consistently across locations. In Metuge and Montepuez, intensive borehole drilling and prolonged water trucking contributed to declining groundwater levels, particularly in areas with limited recharge potential. Multiple agencies often drilled boreholes in close proximity without coordinated hydrogeological assessments, intensifying aquifer stress. In Pemba and Quissanga, poorly sited emergency latrines contributed to soil and groundwater contamination, especially in low-lying and flood-prone settlements, aligning with documented risks of rapid infrastructure deployment in fragile contexts (UNICEF, 2022; Global WASH Cluster, 2021).

Material use and waste generation emerged as another critical theme. Field engineers and hygiene promoters highlighted extensive timber use for WASH superstructures and the proliferation of plastic waste from hygiene kits. While these materials facilitated rapid deployment, they also contributed to localized deforestation and persistent solid waste accumulation. The absence of structured waste segregation, recycling, or decommissioning plans further intensified environmental pressures (Samantha & Frances, 2020; Manaktala, 2024).

Eco-innovation and adaptive practices were evident but fragmented. In Pemba, Metuge, and Montepuez, solar-powered water systems reduced fuel dependence and operational emissions. Community-level initiatives included reusable menstrual hygiene products and small-scale production, particularly among women's groups. Pilot EcoSan toilets and greywater reuse were reported in institutional settings, while bamboo and compressed-earth materials were explored for WASH structures. These innovations illustrate adaptive, resilience-oriented responses under constrained conditions (Samantha & Frances, 2020).

However, respondents emphasized that such innovations remain ad hoc, dependent on organizational discretion and donor flexibility. Provincial WASH Cluster coordinators noted the lack of standardized sustainability benchmarks, limited technical capacity within implementing agencies, and donor frameworks that prioritize coverage indicators over environmental outcomes (UNDP, 2022; IASC, 2023).

Institutional and governance influences shape environmental outcomes. The findings demonstrate that environmental impacts are systematically mediated by operational decisions, material choices, coordination gaps, and governance arrangements. Political ecology perspectives highlight the role of institutional authority, resource allocation, and regulatory oversight, particularly SDPI and district governance, in shaping ecological consequences (Perreault et al., 2022). Strengthening these interfaces, embedding environmental screening into project cycles, and aligning donor requirements with sustainability objectives provide viable pathways for transitioning emergency WASH programming in Cabo Delgado from reactive relief toward environmentally accountable and resilient practice (UNEP/OCHA, 2020; Oxfam, 2023).

Nature of Emergency WASH Interventions

This section presents an analytical overview of major emergency WASH interventions across conflict-affected districts, integrating data from semi-structured interviews, KIIs, FGDs, and field assessments in Pemba, Metuge, Montepuez, Mocímboa da Praia, and Quissanga. Multi-source triangulation allowed for insights into operational realities, community experiences, and institutional perspectives on sustainability and environmental accountability.

Water Supply Interventions

Water interventions formed the core of emergency WASH programming, reflecting the immediate needs arising from displacement, infrastructure damage, and contamination. Four dominant modalities were identified: borehole drilling and rehabilitation, solar-powered pumping, water trucking, and rainwater harvesting. While universally deemed lifesaving, implementation choices shaped by hydrogeology, population density, security, and institutional capacity produced uneven environmental outcomes across districts.

In high-density urban areas like Pemba, boreholes, solar pumping, and water trucking were combined. Solar systems reduced fuel reliance, yet water trucking remained essential due to infrastructural gaps, raising concerns over financial and carbon costs (Global WASH Cluster, 2021; Sphere, 2018). Rural districts such as Metuge and Montepuez relied more on borehole drilling, supplemented by rainwater harvesting. Rainwater systems provided seasonal relief but required technical oversight to remain functional (Joint Action for Water, 2024; UNHCR, 2024).

Institutional actors in Montepuez reported declining borehole yields from over-abstraction, a concern independently confirmed by NGO engineers (GOV-Montepuez-1; NGO-Montepuez-1). Coastal districts, including Mocímboa da Praia and Quissanga, prioritized rehabilitation over new drilling due to insecurity and logistical constraints, reducing environmental disturbance but highlighting gaps in groundwater monitoring (UNEP/OCHA, 2020; Sphere, 2018).

Sanitation Infrastructure

Sanitation emerged as both critical and environmentally sensitive. Emergency latrines, mobile toilets, and hygiene promotion addressed public health needs but frequently generated secondary environmental risks, particularly in dense and hydrologically fragile settings (UNICEF, 2023; UNDP, 2022). Poor latrine siting led to flooding, pit collapse, odors, vector proliferation, and contamination of shallow wells (FGD – 25 de Junho; FGD – Namuapala, Appendix V). Inadequate sludge management further compounded soil and surface water contamination (Field Assessment – 25 de Junho, Appendix VI; Samantha & Frances, 2020).

Insecurity, limited contractor availability, and short project cycles constrained effective sanitation infrastructure and maintenance, reinforcing the environmental vulnerabilities of emergency interventions.

Conclusion

The study has several overarching conclusions emerge regarding emergency WASH programming and environmental sustainability in Cabo Delgado. First, emergency WASH interventions in conflict-affected contexts function as environmentally consequential systems rather than neutral responses. While effective in restoring life-saving services, their cumulative ecological footprint manifested through groundwater depletion, sanitation-related contamination, deforestation, and waste accumulation is substantial and measurable. These findings underscore that environmental considerations cannot be treated as secondary in humanitarian WASH programming without jeopardizing long-term recovery and resilience.

Second, environmental degradation in emergency WASH is driven less by technical ignorance than by operational structures and governance constraints. Practices such as poorly sited latrines, uncontrolled water abstraction, and non-sustainable material use are embedded within humanitarian modalities that prioritize rapid deployment, standardization, and short-term outputs over environmental planning. This aligns with Political Ecology perspectives, illustrating that environmental outcomes are shaped by institutional priorities, power dynamics, and policy decisions rather than by technical limitations alone.

Third, eco-innovative practices provide viable pathways to reduce the environmental footprint of emergency WASH interventions without compromising service delivery. Evidence from Cabo Delgado including solar-powered water systems, community-led sanitation initiatives, and reusable hygiene materials demonstrates that sustainability and emergency responsiveness can coexist. When supported by local governance structures and community participation, these approaches enhance ecological protection and system resilience, consistent with principles of Resilience Thinking.

Fourth, embedding environmental sustainability into emergency WASH programming is fundamentally a governance challenge. Weak regulatory capacity, fragmented coordination, and limited oversight constrain the systematic adoption of sustainable practices. Nevertheless, the study shows that incremental institutional reforms such as environmental screening protocols, inter-agency coordination mechanisms, and district-level capacity building can significantly strengthen environmental accountability.

Theoretical contributions of this research include advancing Political Ecology by empirically demonstrating how humanitarian WASH interventions redistribute environmental risks within fragile contexts, often impacting already vulnerable communities and ecosystems. Simultaneously, the study extends Resilience Thinking by illustrating how adaptive, locally grounded, and environmentally conscious practices can enhance socio-ecological resilience, even amid conflict and displacement.

Overall, this study contributes to the emerging discourse on green humanitarianism by providing grounded empirical evidence from Cabo Delgado that environmentally responsible emergency WASH programming is both necessary and operationally feasible, highlighting practical and theoretical pathways for sustainable humanitarian action.

Recommendations

The recommendations presented here are directly derived from the empirical findings and analytical conclusions of this study. They respond to operational, environmental, and governance challenges identified in emergency WASH programming across conflict-affected districts of Cabo Delgado, including Pemba, Metuge, Montepuez, and Quissanga. Each recommendation is explicitly traceable to documented evidence and aligned with the study's objectives on environmental impact assessment, operational drivers, eco-innovation, and sustainability integration.

1. **Recommendations for Non-Governmental Organizations (NGOs)**

Empirical findings indicated that key environmental impacts including groundwater depletion, sanitation-related contamination, deforestation, and unmanaged waste were linked to the absence of systematic environmental screening and weak integration of safeguards during project design and implementation. Rapid emergency deployment often prioritized speed over ecological assessment, as observed in Metuge and Montepuez.

- Institutionalize Environmental Accountability: NGOs should mandate hydrogeological and environmental assessments prior to borehole drilling, latrine construction, or infrastructure placement, even under emergency conditions. Tools such as NEAT should be adopted as compulsory instruments rather than optional safeguards.
- Integrate Environmental Indicators into Monitoring: Monitoring frameworks should extend beyond service coverage metrics to track groundwater trends, latrine siting compliance, drainage performance, and solid and liquid waste management outcomes, ensuring environmental risks are visible and systematically addressed.
- Strengthen Local Capacity: NGOs should invest in continuous training for staff, artisans, and community actors in eco-sanitation, renewable energy systems, and waste management, addressing sustainability gaps that typically emerge post-intervention due to limited local technical ownership.
- Promote Eco-Procurement and Community-Led Practices: Procurement should prioritize biodegradable, reusable, and locally produced materials. Scaling community-driven initiatives, such as reusable menstrual hygiene kits produced by women's cooperatives, strengthens environmental stewardship and resilience, as evidenced in Montepuez.

2. Recommendations for Donor Agencies

Findings revealed that donor funding structures, including short cycles, rigid output targets, and pressure for rapid disbursement, often drive environmentally harmful operational practices.

- Embed Environmental Sustainability in Funding Criteria: Environmental screening, mitigation planning, and ecological reporting should be mandatory for funding approval and evaluation, ensuring accountability is coupled with financial oversight.
- Support Adaptive, Multi-Year Programming: Flexible, longer-term funding should enable infrastructure maintenance, environmental monitoring, and iterative adjustments beyond immediate emergency phases, supporting resilience-informed, feedback-driven approaches.
- Incentivize Eco-Innovation: Donors should fund pilot initiatives that test renewable energy technologies, circular waste management, and context-appropriate sanitation solutions. Evidence from Cabo Delgado shows that solar-powered systems and reusable hygiene products reduced environmental pressure without compromising service delivery.
- Ensure Environmental Reporting and Transparency: Projects aligned with global commitments, including SDG 13 and the Paris Agreement, should be required to publish environmental impact summaries and mitigation results, operationalizing the study's conclusion that environmental stewardship must be embedded within accountability structures.

3. Recommendations for Policymakers and Government Bodies

Weak institutional coordination, limited regulatory authority, and insufficient oversight were identified as central barriers to sustainable WASH programming. Poor coordination contributed to borehole duplication, unsafe sanitation siting, and unmanaged waste.

- Institutionalize Environmental Safeguards: Government bodies including SDPI, the Ministry of Public Works, and the National Directorate for Water and Sanitation should integrate environmental safeguards into national emergency WASH policies.
- Establish District-Level Monitoring Committees: Multi-stakeholder committees, including government officials, NGOs, and community representatives, should oversee site inspections, compliance verification, and waste management, addressing accountability gaps identified in Quissanga.
- Standardize Siting and Infrastructure Protocols: National policy should enforce minimum distances between water sources and sanitation facilities require borehole permitting based on hydrogeological assessments, and prioritize rehabilitation over new drilling. Municipal authorities should integrate waste management into emergency planning to prevent post-intervention environmental degradation.

4. Recommendations for Academic and Research Institutions

The study identified significant data gaps in environmental monitoring and impact assessment, limiting both policy formulation and operational improvement.

- Conduct Longitudinal and Comparative Studies: Research should track ecosystem recovery following emergency interventions, including aquifer recharge, soil stability, and biodiversity restoration.
- Incorporate Life-Cycle Analysis: Quantifying carbon, energy, and material footprints of WASH interventions address underestimation of environmental impacts and supports evidence-based planning.
- Explore Social and Institutional Dimensions of Eco-Innovation: Research should examine how local norms, gender dynamics, and governance arrangements influence adoption and maintenance of sustainable technologies.
- Foster Collaborative Research Platforms: Partnerships between academia, NGOs, and government agencies can translate research into training for local technicians and policymakers.
- Advance Operational Research: Studies on low-cost fecal sludge treatment, waste reuse, and environmentally appropriate sanitation solutions tailored to conflict-affected settings can provide practitioners with practical alternatives to harmful emergency practices.

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