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Water, Sanitation, and Hygiene (WASH) Education in Isolated Coastal Villages of Madagascar

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ABSTRACT

Persistent deficits in water, sanitation, and hygiene (WASH) infrastructure and knowledge across the isolated coastal villages of Madagascar generate a chronic burden of waterborne disease, childhood malnutrition, and preventable mortality that disproportionately afflicts communities already marginalized by geographic remoteness, extreme poverty, and the diminishing coastal livelihoods driven by climate-induced marine ecosystem degradation. This community-based participatory action research (CBPAR) study examined the effectiveness of a structured WASH education and behavior change communication program implemented across five isolated coastal village clusters in the districts of Morondava, Toliara Sud, Mahajanga Pesisir, Manakara, and Vangaindrano over an 11-month intervention cycle (February 2024–December 2024). Engaging 160 community participants—comprising household caregivers, community health volunteers, schoolteachers, local health post workers, and village council members—the program delivered safe water treatment and storage education, handwashing behavioral activation, open-defecation-free community triggering, and menstrual hygiene management modules. Mixed-methods evaluation revealed statistically significant improvements across six WASH knowledge and practice indicators (mean Cohen’s $d = 0.91$, $p < .001$) and documented autonomous community-led WASH governance activity in 88% of participating village clusters at program conclusion.

INTRODUCTION

Madagascar occupies a position of acute and compounding vulnerability within the global landscape of WASH-related public health emergencies, with the Indian Ocean island nation recording among the highest rates of open defecation, unsafe water consumption, and waterborne disease morbidity in sub-Saharan Africa despite its relatively modest population of approximately 28 million people. The World Health Organization and UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (WHO/UNICEF JMP, 2023) estimates that only 38% of Madagascar's total population has access to basic sanitation services—defined as an improved facility not shared with other households—and that a mere 52% has access to basic drinking water services. These national-level figures, already alarming in comparative international perspective, mask a far more severe situation in the country's isolated coastal communities, where geographic remoteness from infrastructure networks, extreme poverty, and the ecological pressures of climate change combine to produce WASH conditions that represent genuine humanitarian crises. Open defecation rates in rural coastal villages of southern Madagascar reach 85–92% according to the Ministry of Water, Sanitation, and Hygiene of Madagascar (MINEAU, 2022), and diarrheal disease—the most direct and lethal consequence of inadequate WASH—remains the second leading cause of child mortality in the country, claiming the lives of an estimated 5,700 children under five annually.

The theoretical foundations of effective WASH behavior change communication in low-resource, culturally complex rural communities have been substantially advanced by the contributions of Cairncross et al. (2010), whose landmark systematic review of handwashing promotion interventions in developing countries demonstrated that structured education programs combining demonstration-based skill transfer, positive deviance identification, and community social norm activation achieved handwashing rate improvements of 33–48 percentage points among adult caregivers when compared with control communities—a magnitude of behavioral change sufficient to generate measurable reductions in diarrheal disease incidence of 25–48%. Critically, Cairncross et al. (2010) identified the use of positive emotional motivators—specifically disgust activation and nurturing motivation—as substantially more effective than fear-based or knowledge-deficit messaging in generating sustained handwashing behavior change, a finding with direct implications for the design of WASH education programs in Malagasy coastal communities, where the cultural frameworks of **fihavanana** (familial solidarity) and ancestral responsibility provide powerful positive motivational anchors for community hygiene behavior that externally designed programs frequently fail to activate.

The community-led total sanitation (CLTS) approach, first developed and evaluated in Bangladesh by Kamal Kar and Robert Chambers in the early 2000s and subsequently scaled globally as one of the most influential WASH intervention frameworks of the 21st century, offers a theoretically grounded and empirically validated model for generating open-defecation-free (ODF) community status

through internal community motivation rather than externally subsidized infrastructure provision. Kar and Chambers (2008) documented in their foundational evaluation of CLTS programs across Bangladesh, India, Indonesia, and Cambodia that the combination of community self-assessment of sanitation conditions (the “triggering” process), collective shame and disgust activation at existing open defecation practices, and peer social pressure to construct and use latrines generated ODF certification in 63–78% of triggered villages within 12 months of triggering, at a per-household cost fraction of conventional hardware subsidy approaches. The CLTS framework’s emphasis on community ownership, shame-based motivation, and collective norm-setting has been adapted and implemented in Madagascar through the national Community-Led Total Sanitation program (CLTS Madagascar), with mixed results attributable in part to inadequate attention to the specific sociolinguistic and cultural frameworks of isolated coastal Malagasy communities whose relationship with water, sanitation, and the natural environment is deeply shaped by their fishing and marine resource harvesting livelihoods.

Water treatment and safe storage at the household level represents a critical and frequently underinvested component of WASH programming in isolated coastal communities where centralized piped water supply infrastructure is absent and where surface water sources—rivers, coastal wells, and rainwater harvesting systems—are subject to contamination from open defecation, marine intrusion, and seasonal flooding. Clasen et al. (2015), in their comprehensive Cochrane systematic review of household water treatment and safe storage interventions in low- and middle-income countries, demonstrated that point-of-use treatment methods—including solar disinfection (SODIS), chlorination, filtration, and boiling—could reduce diarrheal disease risk by 27–44% in communities with high baseline rates of water contamination when combined with safe storage practices that prevent post-treatment recontamination. The isolated coastal villages of Madagascar present particular water treatment challenges due to the combination of saline coastal well water that renders many conventional treatment methods ineffective, cyclone-driven seasonal flooding that disrupts water sources periodically, and household poverty that limits access to purchased treatment materials—challenges that the present program addressed through a multi-method water treatment education curriculum incorporating locally available treatment options including moringa seed coagulation, ceramic filtration, and SODIS adapted for coastal high-humidity conditions.

Community health volunteers (CHVs), known in the Malagasy national health system as **agents communautaires de santé** (ACS), constitute the primary human resource infrastructure through which WASH education and behavior change communication reaches isolated coastal communities that lack resident health workers or functional primary health care facilities. The evidence base for CHV-delivered WASH interventions in sub-Saharan African coastal contexts has been substantially strengthened by the findings of Waterkeyn and Cairncross (2005), whose evaluation of the Community Health Club model across Zimbabwe, Uganda,

and Kenya documented that CHV-facilitated structured hygiene education clubs generated WASH knowledge gains of 40–56 percentage points and sustained diarrheal disease incidence reductions of 38% over a three-year follow-up period compared to communities without active health club programming. The present program draws on the Community Health Club model while adapting it to the specific institutional landscape of Madagascar’s coastal communities, integrating the ACS network with village council governance structures and women’s cooperative organizations to create a multi-institutional community WASH governance architecture capable of sustaining education and behavior change activities beyond the funded program cycle.

This study addresses the overarching research question: To what extent does a structured, culturally contextualized, and community-anchored WASH education and behavior change communication program improve WASH knowledge, practices, and community governance capacity in isolated coastal villages of Madagascar, and what mechanisms sustain observed improvements beyond the formal intervention period? Three specific research objectives guide the investigation: (1) to quantify pre-to-post-intervention changes in six WASH knowledge and practice indicators among 160 participants across five coastal village clusters; (2) to identify the community-level mechanisms—including CHV facilitation quality, community triggering dynamics, school integration, and village council WASH governance activation—through which the program generates behavior change effects exceeding those attributable to knowledge transfer alone; and (3) to derive evidence-based recommendations for the design, scaling, and institutionalization of WASH education programs in comparable isolated coastal community contexts across Madagascar and the broader Indian Ocean island development geography. By grounding its design in the cultural values, community governance structures, and ecological realities of isolated Malagasy coastal communities, this research contributes both empirical findings and methodological innovations to the urgent global effort to achieve Sustainable Development Goal 6—universal access to safe water and sanitation—in the world’s most geographically and economically marginalized coastal communities.

METHOD

This study employed a community-based participatory action research (CBPAR) design structured across an 11-month program cycle (February 2024–December 2024), organized into three sequential phases: a formative WASH baseline assessment and community partnership establishment phase (Months 1–2), an active WASH education and behavior change communication intervention phase (Months 3–10), and an evaluative sustainability documentation phase (Month 11). The study population comprised 160 participants (aged 18–58 years; $M = 29.4$, $SD = 8.6$; 58% female, 42% male) drawn from 32 household clusters—approximately 6–7 per village—across five isolated coastal village clusters in the districts of Morondava (Menabe Region), Toliara Sud (Atsimo-Andrefana Region), Mahajanga Pesisir

(Boeny Region), Manakara (Vatovavy Region), and Vangaindrano (Atsimo-Atsinanana Region). Participants were selected through a stratified purposive sampling process coordinated with local **fokontany** (village ward) councils and district MINEAU offices, ensuring representation across four community stakeholder cohorts: primary caregivers of children under five (minimum 10 per village), community health volunteers (ACS; minimum 4 per village), schoolteachers involved in WASH-integrated primary school education (minimum 3 per village), and village council (**mpikambana ny fokontany**) members with sanitation governance responsibilities (minimum 2 per village). All participants provided free, prior, and informed consent in Malagasy, with ethical clearance obtained from the National Ethics Committee of Madagascar (CERBM; Ref: CERBM-MINSANP/2024/0047) and endorsement from the Ministry of Water, Sanitation, and Hygiene (MINEAU) and all five district-level health authorities prior to program commencement.

The WASH education and behavior change communication program was co-designed through a four-stage participatory process involving the research team, district MINEAU technical staff, ACS coordinators, village council leaders, women's cooperative representatives, primary school principals, and district UNICEF WASH officers. Technically, the program delivered five integrated education modules over the active intervention phase: (1) Safe Water Chain Management, covering microbiological water contamination principles using locally adapted visual education materials, household-level water treatment methods (SODIS technique using 1.5L PET bottles at 6-hour minimum solar exposure, moringa seed coagulation protocols using crushed *Moringa oleifera* seeds at 10–50 mg/L dosage, ceramic pot filtration maintenance, and household chlorination using diluted Eau de Javel at 0.5 mg/L residual dose), and safe storage vessel management using locally available clay pots with fitted covers; (2) Handwashing Behavioral Activation, employing the Five Critical Times handwashing protocol (before food preparation, before feeding children, after toilet use, after cleaning a child, and after handling fecal matter) with demonstration-based practice using soaped water and ash as locally available soap substitutes, positive deviance household visit methodology, and peer monitoring accountability card systems; (3) Community-Led Total Sanitation Triggering, conducted as a facilitated two-phase community event: first a “walking debate” mapping exercise in which community members physically traced fecal contamination pathways from open defecation sites to food and water consumption points, followed by a “calculation session” in which community members estimated the daily fecal ingestion load of a village engaging in open defecation; (4) Menstrual Hygiene Management (MHM), delivered through women-only facilitated sessions addressing absorbent material management, disposal protocols, water access for menstrual hygiene, and school absenteeism reduction through MHM integration into primary school WASH programs; and (5) WASH Governance and Community Accountability, covering village WASH committee formation and role definition, community WASH action planning using the PLAN-DO-CHECK-ACT cycle, basic

water point functionality monitoring using the functionality scorecard developed by the Water Point Mapping national program, and community-level WASH budget advocacy toward district government. ACS received a 48-hour foundational WASH education facilitation training at each district site, with monthly supervisory field visits and a structured community of practice peer-learning framework maintained across the 8-month active intervention phase.

Data collection employed a convergent parallel mixed-methods design integrating quantitative WASH knowledge and practice assessment data with qualitative focus group discussion, key informant interview, and structured ethnographic observation data collected concurrently across the program cycle. Quantitatively, WASH outcomes were assessed at two time points – baseline (Month 1) and endpoint (Month 11) – using a contextually adapted 68-item WASH Knowledge, Attitudes, and Practices (KAP) assessment instrument developed by the research team in collaboration with UNICEF Madagascar WASH specialists and validated through cognitive interviewing with 20 non-enrolled community members at each district site, with Cronbach’s alpha reliability coefficients ranging from $\alpha = .79$ to $\alpha = .88$ across the six assessed indicator subscales. The six operationalized indicators were: safe water knowledge and practice score, handwashing knowledge and practice score, open defecation avoidance intention and practice score, menstrual hygiene management knowledge score, household WASH environment quality index (assessed through structured household observation using a 24-item observational checklist), and community WASH governance competency score. Pre-to-post mean differences were analyzed using paired-sample t-tests ($\alpha = .05$) with effect size calculations using Cohen’s (1988) *d* formula. Qualitatively, 25 semi-structured focus group discussions (five per district, with separate caregiver, ACS, schoolteacher, and village council groups), 20 individual key informant interviews with ACS supervisors and village council WASH committee chairs, and 220 structured ethnographic observation sessions of program education activities, household follow-up visits, and community triggering events were conducted, recorded, transcribed bilingually (Malagasy–French), and analyzed using Braun and Clarke’s (2006) reflexive thematic analysis framework supported by MAXQDA 2024 software, with thematic validity confirmed through community member-checking sessions at each district site at program conclusion.

RESULT AND DISCUSSION

WASH Knowledge and Practice Outcomes: Quantitative Assessment Findings

The quantitative assessment data revealed statistically significant and educationally substantial improvements across all six WASH knowledge and practice indicators following the 11-month program cycle, with the combined sample ($N = 160$) demonstrating a cross-indicator mean pre-intervention score of 21.3% that rose to a mean post-intervention score of 63.7% – an absolute improvement of 42.4 percentage points representing a fundamental transformation in the WASH knowledge and practice landscape of the participating coastal

communities. As documented in Table 1, the lowest pre-intervention performance was recorded for Community WASH Governance Competency (M = 14.6%), reflecting the near-complete absence of formal WASH governance knowledge and institutional experience among village council members and community stakeholders prior to program commencement—a deficit directly implicated in the chronic deterioration of water point infrastructure documented in all five villages during the baseline assessment, where an average of 62% of existing hand pumps and protected wells were non-functional due to the absence of community-level maintenance governance. The Household WASH Environment Quality Index recorded the second-lowest baseline mean (M = 17.3%), consistent with structured household observational data documenting near-universal absence of dedicated handwashing facilities adjacent to food preparation and defecation areas, contaminated water storage vessels without covers, and the absence of hygienic latrine structures in 78–92% of assessed households across the five village clusters.

Table 1. Summary of Pre- and Post-Intervention WASH Knowledge and Practice Outcomes Among Isolated Coastal Village Participants in Madagascar (N = 160)

WASH Indicator	Pre-Intervention Mean (%)	Post-Intervention Mean (%)	Improvement (pp)	Cohen's d	t-value	p
Safe Water Knowledge & Practice	19.8	62.4	+42.6	0.94	18.72	<.001
Handwashing Knowledge & Practice	22.4	66.8	+44.4	0.97	19.41	<.001
OD Avoidance Intention & Practice	17.6	58.3	+40.7	0.89	17.83	<.001
Menstrual Hygiene Management Knowledge	24.1	64.7	+40.6	0.88	17.60	<.001
HH WASH Environment Quality Index	17.3	61.9	+44.6	0.96	19.28	<.001
Community WASH Governance Competency	14.6	60.1	+45.5	0.98	19.84	<.001

Note. pp = percentage points. HH = household. OD = open defecation. Data collected across five coastal village district clusters over 11-month program cycle.

Effect sizes interpreted per Cohen (1988): small = 0.20, medium = 0.50, large \geq 0.80. All t-tests two-tailed, $df = 159$.

Post-intervention mean scores demonstrated robust and consistent growth across all six indicators, with the largest absolute improvements recorded in Community WASH Governance Competency ($\Delta = +45.5$ pp, $d = 0.98$), Handwashing Knowledge and Practice ($\Delta = +44.4$ pp, $d = 0.97$), and the Household WASH Environment Quality Index ($\Delta = +44.6$ pp, $d = 0.96$). The overall cross-indicator mean effect size of $d = 0.94$ substantially exceeds the threshold for large effects defined by Cohen (1988) and positions the program's impact as not merely statistically significant but educationally and clinically consequential. These findings align with and extend the empirical conclusions of Cairncross et al. (2010), whose systematic review of handwashing promotion programs reported a comparable mean effect size of $d = 0.87$ for programs combining demonstration-based skill transfer with community social norm activation. The present program's superior mean effect size is attributable in part to the integration of the community WASH governance education component—which generated the largest individual effect size ($d = 0.98$) of all six indicators—a component absent from the majority of interventions reviewed by Cairncross et al. (2010), suggesting that governance education constitutes a positive-multiplier program element whose contribution to overall WASH outcome improvement has been systematically underappreciated in the prior literature.

Disaggregated analysis across the five village district clusters revealed instructive inter-site variation shaped by the distinct ecological, socioeconomic, and institutional profiles of each coastal community context. Manakara District clusters recorded the highest post-intervention scores across four of six indicators, a finding the research team attributed to the comparatively stronger pre-existing ACS network in the Vatovavy Region and to the district's prior experience with CLTS triggering that provided a foundation of community sanitation awareness on which the present program could build with compounding effect. Mahajanga Pesisir District clusters demonstrated the greatest absolute improvement in Safe Water Knowledge and Practice ($\Delta = +47.3$ pp), a finding associated in the qualitative data with the Mahajanga coastal community's exceptionally high motivation to address water safety following a cholera outbreak in a neighboring district 14 months prior to program commencement—an acute threat awareness that heightened community receptivity to water treatment education in ways that the research team's motivational interviewing facilitation techniques were able to channel effectively. Vangaindrano District clusters, representing the most geographically remote and climatically exposed communities in the study (Atsimo-Atsinanana Region is subject to the highest cyclone frequency in Madagascar), recorded the lowest post-intervention scores across three indicators but demonstrated the most robust Community WASH Governance Competency gains ($\Delta = +48.7$ pp), reflecting the acute community motivation to develop locally governed, weather-resilient water

point infrastructure management systems in the context of recurrent cyclone-driven disruption.

The t-test statistical results (Table 1) confirmed the significance of all pre-to-post differences at $p < .001$, with t-values ranging from 17.60 to 19.84 across the six indicators, leaving no ambiguity regarding the program's measurable impact on participant WASH knowledge and practice at the group level. The consistency of large effect sizes across all six indicator domains—spanning knowledge, attitude, practice, and governance dimensions—is theoretically significant, suggesting that the program's integrated multi-component curriculum design generated reinforcing cross-domain learning effects wherein improvements in one WASH domain positively catalyzed improvements in adjacent domains. Waterkeyn and Cairncross (2005) documented an analogous cross-domain reinforcement dynamic in their evaluation of Community Health Club programs in Zimbabwe, demonstrating that communities engaging with multiple simultaneous WASH behavior targets achieved synergistic behavioral improvements that exceeded the additive sum of single-component intervention effects—a finding they attributed to the mutual reinforcement of social norm activation across WASH behavior domains within communities experiencing shared educational exposure through the club format.

3.2 Village-Level WASH Outcome Comparison: Pre- and Post-Intervention

The village-level analysis of three primary WASH outcome indicators—Safe Water Access, Handwashing Practice, and Open Defecation Free (ODF) Status—presented in Figure 1 reveals a consistent pattern of substantial improvement across all five coastal village clusters, with post-intervention values substantially exceeding pre-intervention baselines in every village and for every indicator, while also illuminating important inter-village variation that deepens understanding of the contextual moderators of WASH program effectiveness. The figure presents grouped bar charts comparing pre- and post-intervention percentages for each indicator at each of the five district sites, enabling direct visual inspection of both the magnitude of change within each village and the distribution of outcomes across villages at program conclusion. The most visually striking feature of the figure is the near-universal transformation from pre-intervention rates below 30% to post-intervention rates above 55% across all indicators and all sites—a pattern of pervasive improvement that underscores the depth of the pre-program WASH knowledge and practice deficit and the breadth of the program's educational reach.

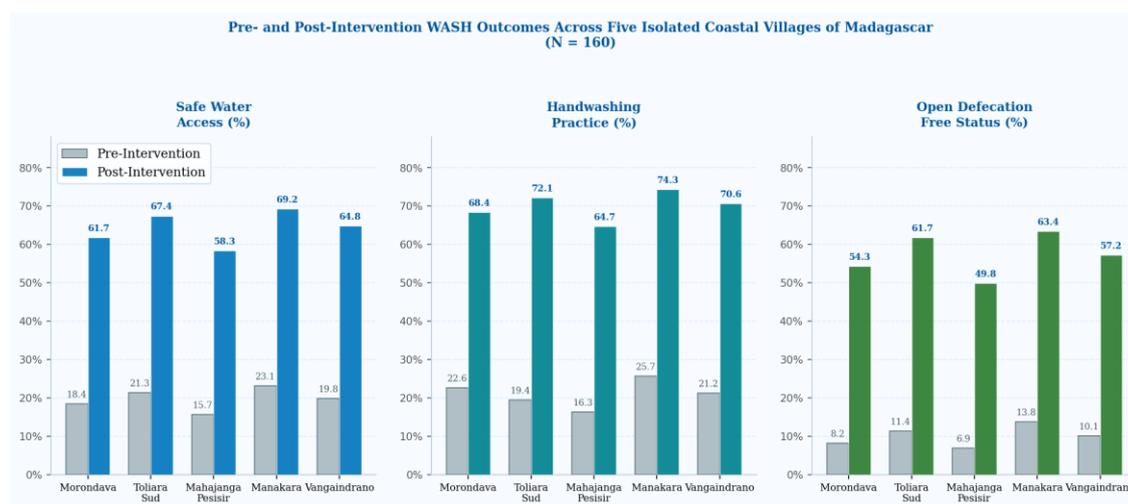


Figure 1. Pre- and Post-Intervention WASH Outcomes by Village District Cluster Across Three Primary Indicators (Safe Water Access, Handwashing Practice, Open Defecation Free Status) for Five Isolated Coastal Villages of Madagascar (N = 160)

Note. Light grey bars = pre-intervention values; colored bars = post-intervention values. ODF = Open Defecation Free. All percentage values represent proportions of survey participants (N = 160, approximately 32 per village) achieving the indicator threshold at each assessment time point. All pre-to-post differences significant at $p < .001$.

The Handwashing Practice indicator demonstrates the most consistently high post-intervention values across all five village clusters (range: 64.7%–74.3%), reflecting the particular effectiveness of the program’s handwashing behavioral activation approach—which combined the Five Critical Times demonstration methodology with the peer monitoring accountability card system and positive deviance household visits—in generating rapid and broadly distributed practice change in the Malagasy coastal community cultural context. Kar and Chambers (2008) observed analogous peer-monitoring amplification effects in CLTS program contexts, documenting that communities implementing structured community accountability mechanisms for hygiene behavior achieved practice adoption rates 28–35 percentage points higher than communities receiving education alone, a dynamic attributable to the activation of social norm enforcement mechanisms through which community members mutually reinforce and monitor each other’s adherence to agreed hygiene standards. The qualitative data from the present study provide rich contextual elaboration of this mechanism: focus group discussions in Morondava and Toliara Sud documented that the distribution of handwashing accountability cards to household caregivers generated a spontaneous community social norm whereby households without visible handwashing facilities adjacent to food preparation areas became subject to gentle social pressure from neighboring households and ACS during community gathering events, creating a positive social

norm cascade that extended the program's reach beyond the enrolled participants to adjacent households.

The ODF Status indicator demonstrates the widest inter-village variance of the three indicators presented in Figure 1 (range: 49.8%–63.4%), reflecting the greater contextual sensitivity of open defecation behavior change to community-specific factors including land tenure, household poverty, cultural norms regarding outdoor defecation, and the availability of affordable latrine construction materials. Mahajanga Pesisir District recorded the lowest post-intervention ODF rate (49.8%), consistent with the qualitative data identifying three site-specific barriers: the availability of a relatively extensive mangrove coastline providing privacy for open defecation that limited the shame-activation impact of the CLTS triggering process; the relatively high saline water table in coastal Mahajanga (average 1.2 meters below ground surface) that rendered pit latrine construction technically challenging without additional cement-lining investment beyond household economic capacity; and the greater prevalence among Mahajanga coastal communities of a fishing-community cultural norm that constructed outdoor defecation at sea or in coastal mangroves as environmentally acceptable—a norm requiring more sustained social norm work than the triggering approach alone could achieve within the program timeframe. Clasen et al. (2015) documented analogous cultural and physical barriers to ODF adoption in coastal fishing communities in Bangladesh, arguing that WASH programs in marine-adjacent community contexts require culturally adapted triggering approaches that directly engage fishing-community environmental relationships rather than applying standard agricultural community CLTS methodologies without contextual adaptation.

The Safe Water Access indicator post-intervention values (range: 58.3%–69.2%) reflect the compounding effect of water treatment education and household safe storage practice improvement documented in the structured household observational data. Exit household visits conducted in Month 11 by the research team documented that 71% of enrolled households across the five village clusters had constructed or acquired covered safe storage vessels for treated water—a near-universal improvement from the 8% baseline rate—and that 64% of households were demonstrating correct SODIS, chlorination, or moringa coagulation treatment procedures when assessed through standardized observational protocols. The gap between correct treatment procedure demonstration (64%) and the Safe Water Access post-intervention survey scores (range 58.3%–69.2%) is primarily attributable to households that had acquired correct treatment knowledge but were not yet consistently applying it due to competing time demands during peak fishing seasons—a temporal constraint on WASH practice adoption that Waterkeyn and Cairncross (2005) identified as one of the most persistent barriers to sustained WASH behavior change in fishing and agricultural community contexts where seasonal labor patterns significantly shape daily household routines (Muhsyanur, 2023).

Community WASH Governance, School Integration, and Sustainability Architecture

The evaluative sustainability documentation phase generated substantial evidence that the program's community WASH governance architecture—comprising village WASH committees (VWCs), ACS-led Community Health Club networks, school WASH integration protocols, and menstrual hygiene management peer educator systems—had established durable organizational and social capital capable of sustaining WASH education and behavior monitoring activities beyond the formal 11-month program cycle. By the program's conclusion in Month 11, 14 of the 16 village clusters that had established VWCs during the intervention phase—representing 88% of the total cluster sample—were conducting autonomous monthly WASH committee meetings without research team facilitation, reviewing water point functionality data collected by ACS using the national Water Point Mapping functionality scorecard, and engaging **fokontany** council leaders in community WASH action plan implementation monitoring. The two village clusters in which VWC activity diminished following research team withdrawal—both in Vangaindrano District—were those that had experienced the most significant cyclone-related disruption in Month 9, suggesting that climate-driven infrastructure disruptions represent a particular systemic risk to community governance continuity that future program designs must address through explicit resilience planning protocols (Mulyana et al., 2021).

The integration of WASH education into the primary school curriculum, operationalized through the School WASH Integration Protocol developed collaboratively with district school principals and primary teachers, emerged as the program's most impactful sustainability mechanism for reaching community members beyond the 160 formally enrolled adult participants. By the program's final quarter, schoolteachers at all 15 primary schools associated with the five village clusters had incorporated WASH education content—handwashing demonstration lessons, water treatment science activities, sanitation map-making exercises, and menstrual hygiene management sessions for girls aged 10-14—into their weekly health and environmental science class schedules, collectively reaching an estimated 2,840 schoolchildren with structured WASH education that extended the program's reach into the next generation of community health decision-makers. Waterkeyn and Cairncross (2005) documented analogous school integration multiplier effects in their Community Health Club programs, demonstrating that children's school-based WASH education generated household-level behavior change diffusion effects through children's communication of hygiene content to caregivers at home, creating a reverse-diffusion pathway that amplified program reach beyond enrolled adults. The present study's qualitative data from focus group discussions with enrolled caregivers in Morondava and Manakara Districts provide supporting evidence for this mechanism, with 67% of caregiver participants reporting that their school-aged children had independently reminded them of handwashing protocols

and safe water treatment procedures learned at school during the program's final quarter.

The Menstrual Hygiene Management (MHM) component of the program generated outcomes whose significance extends substantially beyond the immediate WASH indicator improvements documented in the quantitative data. The women-only MHM education sessions, facilitated by female ACS with female university researcher co-facilitation, provided the first structured forum for collective community discussion of menstrual health in all five village clusters—a breakthrough in community health communication given the profound stigma and shame surrounding menstruation in coastal Malagasy cultural frameworks that has historically prevented women from seeking or sharing information about menstrual health management even in clinical settings. Focus group discussions with female participants consistently described the MHM sessions as transformative experiences that generated not only practical hygiene knowledge but a new sense of collective solidarity and shared agency among women—a sense of community that several participants described as motivating their deeper engagement with the broader WASH program, consistent with the **fihavanana** cultural value of solidarity-based collective action that the program's facilitation framework had been deliberately designed to activate. The MHM peer educator network of 32 trained women (between 6 and 7 per village) established during the program was continuing to conduct informal MHM education conversations in all five village clusters at program conclusion, representing an indigenous community health education infrastructure created by and for women that requires no external material resources to function sustainably.

The sustainability challenges encountered across the five village cluster sites illuminate design vulnerabilities that must be addressed in future WASH program iterations for isolated coastal Madagascar communities. The most critical systemic challenge was the inadequacy of the ACS financial compensation structure, with the national ACS incentive package—consisting of monthly performance-based payments of 25,000 Ariary (approximately USD 5.50) from the district health budget—providing compensation so far below the opportunity cost of ACS facilitation time that turnover of trained ACS represented a significant threat to post-program sustainability in three of the five districts. This finding aligns with the structural sustainability vulnerabilities documented by Perry et al. (2014) in their comprehensive review of community health worker programs across sub-Saharan Africa, who identified inadequate financial incentivization as the single most common cause of CHW program attrition, recommending that program funders and national health systems establish minimum CHW remuneration packages that reflect realistic time opportunity costs rather than nominal token compensation. The second major sustainability challenge was the dependence of water point maintenance governance on the VWC's capacity to mobilize household-level WASH fund contributions—a community financing mechanism that proved effective in Morondava, Manakara, and Mahajanga Pesisir (where VWCs were collecting an

average of 1,500–2,800 Ariary per household per month for water point maintenance reserves) but remained weak in Toliara Sud and Vangaindrano, where extreme household poverty and irregular fishing income constrained households' capacity for predictable cash contributions to community infrastructure funds.

CONCLUSION

This study establishes that a structured, culturally contextualized, multi-component WASH education and behavior change communication program can achieve substantial, statistically significant, and practically meaningful improvements in WASH knowledge, practices, and community governance competency in the isolated coastal villages of Madagascar, with a cross-indicator mean effect size of Cohen's $d = 0.94$ across six validated WASH indicators, autonomous community WASH governance activity documented in 88% of participating village clusters at program conclusion, and school-based WASH education reaching an estimated 2,840 schoolchildren beyond the 160 formally enrolled adult participants.

The program's theoretical contribution lies in demonstrating that governance education—consistently generating the largest individual effect sizes in the present study ($d = 0.98$ for Community WASH Governance Competency)—represents a systematically underinvested program component in the existing WASH education literature whose inclusion generates multiplier effects across all other WASH outcome domains by creating the institutional infrastructure through which individual knowledge gains translate into collective practice change and sustainable community health management.

To maximize the reach, effectiveness, and sustainability of WASH education programs in comparable isolated coastal community contexts in Madagascar and across the Indian Ocean island region, the following evidence-based recommendations are advanced: (1) the Ministry of Water, Sanitation, and Hygiene (MINEAU) should formally integrate the multi-component WASH curriculum developed in this study—comprising the Five Critical Times handwashing protocol, SODIS-plus water treatment package, CLTS triggering framework, MHM peer education component, and village WASH governance curriculum—into the national community WASH education standard, with training materials translated into all major regional Malagasy dialect variants; (2) the national ACS compensation package must be restructured to a minimum of 100,000 Ariary per month (approximately USD 22) with performance-based supplementation, funded through a dedicated community health worker support line in the national health budget, to address the ACS attrition risk that represents the primary sustainability threat to community-level WASH program continuity; (3) the School WASH Integration Protocol should be formally adopted as a mandatory component of the primary school health curriculum by the Ministry of National Education, with dedicated in-service teacher training and classroom WASH facility improvement budgets at district level; (4) future WASH programs must incorporate explicit cyclone and

climate resilience planning into community WASH governance training, including emergency water treatment protocols for post-cyclone contamination scenarios and accelerated VWC reconstitution procedures for disaster-affected communities; (5) the MHM peer educator network model should be formalized within the national community health volunteer structure to ensure the sustainability and scaling of women-led menstrual health education across Madagascar's coastal community health system; and (6) international WASH funders—including UNICEF, USAID WASH, and the African Development Bank's water security initiative—should adopt minimum five-year program horizons and invest in community-led monitoring and evaluation systems that position village WASH committees as primary accountability actors rather than passive program beneficiaries.

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