Open Access Journal
JOURNAL OF COMMUNITY SERVICE

Improving Clean Water Practices through Community Engagement in Remote Cocoa-Farming Villages of São Tomé

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ARTICLE INFO

Received June 6, 2024
Revised June 17, 2024
Accepted July 17, 2024
Published July 28, 2024

Keywords:
clean water, WASH, São Tomé, cocoa-farming communities, waterborne disease, community engagement

ABSTRACT

Access to safe drinking water remains one of the most persistent and consequential development challenges facing rural communities in Sub-Saharan Africa, and in the small island developing state of São Tomé and Príncipe—where remote cocoa-farming villages combine geographic isolation, inadequate sanitation infrastructure, and heavy reliance on unprotected spring and river water—the burden of waterborne disease constitutes a preventable public health emergency. This community service study evaluates a six-month participatory water, sanitation, and hygiene (WASH) improvement programme implemented across thirteen remote cocoa-farming villages in the Lembá and Caué Districts of São Tomé Island, engaging 216 households. Using a single-group longitudinal design with baseline, three-month, and six-month measurements, the programme integrated waterborne disease education, household water treatment training, handwashing behaviour change, latrine construction, spring protection, and community WASH governance capacity building. Findings demonstrate statistically significant improvements in all ten WASH indicators measured, including a 64.6 percentage-point increase in household water treatment practices and a 48.7 percentage-point reduction in E. coli-positive household water samples. These results advance contextually grounded evidence for community-led

WASH improvement in remote agricultural island communities.

INTRODUCTION

Access to safe drinking water, adequate sanitation, and sound hygiene practices—collectively addressed under the international WASH framework—constitutes one of the most foundational prerequisites for human health, dignity, and development, yet remains unavailable to hundreds of millions of people in rural Sub-Saharan Africa despite decades of targeted international investment and successive development goal commitments. The World Health Organization and UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (WHO/UNICEF JMP, 2023) estimates that 748 million people globally lack access to safe managed drinking water services, with rural populations in low-income countries bearing a disproportionate share of this burden: in many Sub-Saharan African nations, rural safe water coverage falls 30 to 50 percentage points below urban coverage, generating a geographic inequality in waterborne disease risk that maps onto and amplifies pre-existing inequalities in income, education, and political representation. São Tomé and Príncipe, a small island developing state in the Gulf of Guinea off the western coast of Central Africa, presents a particularly instructive case of this rural–urban WASH divide: while the national capital city of São Tomé has benefited from sustained infrastructure investment, the remote agricultural communities of the island's interior and southern districts—where smallholder cocoa farming constitutes the primary livelihood for an estimated 45% of the national population—continue to rely predominantly on unprotected spring, river, and rainwater sources that carry substantial microbiological contamination risks. Prüss-Üstün et al. (2019), in their comprehensive global analysis of water, sanitation, and hygiene attributable disease burden, estimate that 829,000 deaths annually are attributable to WASH-related diseases globally, with Sub-Saharan Africa accounting for the largest share; in the São Tomé context, diarrhoeal disease consistently ranks among the leading causes of under-five mortality and the most frequent cause of outpatient consultations at district health centres.

The particular intersection of smallholder cocoa farming with WASH vulnerability in São Tomé's remote village communities generates a distinctive risk profile that mainstream WASH programming frameworks rarely address with adequate specificity. Cocoa farming in São Tomé is concentrated in highland forested areas where seasonal rainfall is abundant—ironically making freshwater physically proximate yet microbiologically hazardous, as the same tropical forest streams and springs that provide drinking water also receive contamination from cocoa processing effluent, animal husbandry, and inadequate household sanitation. Water contamination in cocoa-growing communities is further compounded by the

labour patterns of the agricultural calendar: during peak harvest and fermentation periods, household members spend extended hours in fields and processing areas, reducing time available for water collection, treatment, and storage activities and increasing the consumption of untreated water from proximate field sources. Bain et al. (2014), in their systematic analysis of drinking water quality in rural areas of low- and middle-income countries, demonstrate that the gap between source water quality and point-of-use water quality in rural households is substantially larger than typically acknowledged in national water coverage statistics, which often report the percentage of the population using an improved water source without accounting for the contamination that occurs during transport, storage, and handling within the household—a distinction particularly consequential in contexts like São Tomé where even households classified as using improved sources frequently store and consume water under conditions that generate faecal-oral contamination.

Community engagement constitutes the methodological and ethical cornerstone of effective WASH programming in remote rural communities, for reasons both practical and principled. Practically, WASH improvements that depend on community members correctly and consistently performing treatment, hygiene, and sanitation behaviours require sustained behaviour change that external agency delivery models cannot maintain beyond the active project period; only programming that genuinely builds community ownership, social accountability, and self-governance capacity for WASH management can generate the institutional sustainability that transforms episodic project-cycle improvements into durable public health gains. Principally, communities experiencing WASH deprivation are not passive beneficiaries awaiting technical solutions but agents with extensive local knowledge about water sources, contamination risks, community governance structures, and cultural practices that shape water use—knowledge that must be engaged rather than bypassed if interventions are to be contextually appropriate and genuinely sustainable. Chambers (1994) articulated this principle foundationally in his critique of top-down rural development approaches, arguing that the primary problem with externally designed rural interventions is not technical inadequacy but epistemological arrogance—the assumption that development professionals know more about poor people's situations, priorities, and options than the people themselves—and that applied to WASH programming this demands approaches that position community members as primary knowledge contributors in needs assessment, solution design, and implementation governance.

São Tomé and Príncipe's national WASH policy framework, anchored in the National Water, Sanitation and Hygiene Strategy 2020–2030 developed with WHO and UNICEF support, establishes community-led total sanitation as the primary modality for rural WASH improvement and commits to achieving universal access to basic safe water services by 2030. However, the remoteness and geographic fragmentation of cocoa-farming villages in the Lembá and Caué Districts—connected to the national capital by a single partially paved road that becomes impassable during heavy rains—generates severe implementation challenges for

government extension services whose personnel, vehicles, and supply chains are concentrated in urban centres. Mehleb et al. (2021), analysing WASH programme coverage in island small island developing states across the African and Indian Ocean regions, document a systematic pattern of what they term geographic access gradient bias in WASH investment: the most remote communities within any national WASH programme receive disproportionately less investment and support relative to their actual need precisely because their remoteness inflates the per-household cost of service delivery in ways that aggregate national coverage statistics conceal. University-based community service programmes, which can leverage academic institutional networks to deploy researchers and facilitators to communities that government extension systems chronically underserve, represent one of the few institutional mechanisms capable of compensating for this access gradient bias in a resource-constrained national context.

The relationship between cocoa agriculture and water governance in São Tomé carries historical dimensions that community WASH programming must engage rather than ignore. The Portuguese colonial plantation system—the roça system—organised both cocoa production and freshwater infrastructure across the island until independence in 1975, creating a legacy of centralised water supply management through plantation estate structures that was never adequately replaced with community-governed water management institutions following land reform and the distribution of former plantation lands to cooperative and smallholder producers. This institutional vacuum in rural water governance—the absence of accountable, community-rooted entities responsible for source protection, distribution infrastructure maintenance, and water quality monitoring—constitutes what Ostrom (1990) identifies as a commons governance deficit: an unmanaged common pool resource whose degradation follows predictably from the absence of community rules, enforcement mechanisms, and shared investment motivation. WASH programming in this context must therefore address not merely individual household behaviours and knowledge but the collective governance architecture required for sustainable community-managed water systems—a dimension that many technically focused WASH interventions overlook in favour of more readily measurable household-level behaviour change metrics.

Despite the recognised severity of WASH deprivation in São Tomé's rural cocoa-farming communities, peer-reviewed evidence on community WASH improvement programmes specifically designed for and evaluated in this context is exceptionally sparse. Published WASH research from São Tomé and Príncipe has predominantly addressed malaria and neglected tropical disease control rather than water and sanitation, leaving a critical evidence gap that constrains both national policy development and the adaptation of evidence-based WASH programming models from better-studied contexts to the specific agricultural, geographic, and cultural characteristics of São Tomé's remote villages. Ferreira and Carvalho (2018), in their review of health research production in Portuguese-speaking African countries, document a systematic under-representation of São Tomé and Príncipe in

health research literature relative to its disease burden, attributing this gap to the absence of strong domestic research institutions and the limited engagement of international researchers with a country whose small size and linguistic specificity reduce its visibility in global health research networks. The present community service study directly addresses this gap by providing the first rigorously evaluated longitudinal assessment of a comprehensive community WASH programme in São Tomé's cocoa-farming villages, contributing contextually grounded evidence to the global WASH programming knowledge base while fulfilling the university community service mandate to the island's most underserved rural populations.

METHODE

This study employed a single-group longitudinal pre-test/post-test design with measurements at baseline, three months, and six months, embedded within a community-based participatory action research framework that positioned village water committees, women's groups, and traditional community leaders as co-designers throughout programme development and implementation. The programme—Água Limpa, Vida Saudável (Clean Water, Healthy Life)—was implemented between February and July 2024 across thirteen purposively selected cocoa-farming villages in the Lembá and Caué Districts of São Tomé Island, with site selection guided by criteria of geographic remoteness (minimum 25 km from the district health centre by road), reliance on unprotected water sources confirmed through baseline water quality testing, and absence of any active WASH programme during the preceding three years; a total of 216 households enrolled across the thirteen sites, with 209 completing the six-month endline assessment (96.8% retention).

Primary household-level outcomes were assessed through a validated WASH knowledge, attitudes, and practices instrument developed in Portuguese and Forro—the dominant local Creole language—through three iterative rounds of expert review and community pre-testing, while E. coli microbiological testing of household water samples was conducted at all three time points using H2S presence-absence test kits validated against conventional culture methods. The six-component programme, comprising waterborne disease and contamination pathway education, household water treatment and safe storage training, handwashing behaviour change sessions, latrine construction facilitation, spring protection works, and community WASH governance capacity building, was delivered by four locally recruited community health facilitators trained during a two-week residential programme at the Universidade de São Tomé e Príncipe. Quantitative data were analysed using repeated-measures ANOVA for continuous outcomes and McNemar's test for binary proportional outcomes with Bonferroni correction for all pairwise comparisons; qualitative data from thirteen post-programme village reflection discussions and twenty in-depth interviews were analysed using Braun and Clarke's (2006) reflexive thematic analysis protocol.

RESULT AND DISCUSSION

Water Treatment Practices and Microbiological Water Quality Improvements

The programme's most immediate and clinically consequential outcomes were recorded in household water treatment practices and the corresponding improvements in microbiological water quality that resulted from their adoption. The proportion of enrolled households reporting consistent use of at least one recommended water treatment method—chlorination using locally procured sodium hypochlorite solution, solar disinfection in clear PET bottles, or boiling—increased from 14.6% at baseline to 79.2% at six months, an absolute improvement of 64.6 percentage points that represents one of the largest single-indicator improvements documented in the African WASH programme evaluation literature for a comparable implementation period. This improvement was paralleled by a statistically significant reduction in E. coli contamination of household drinking water samples: the proportion of household water samples testing positive for E. coli using H2S presence-absence tests declined from 71.4% at baseline to 22.7% at six months—an absolute reduction of 48.7 percentage points (McNemar's $\chi^2 = 109.4$, $p < .001$). Clasen et al. (2015), in their Cochrane systematic review of water quality interventions for diarrhoea prevention, report that point-of-use water treatment interventions producing comparable reductions in faecal indicator bacteria contamination are associated with a 30–40% reduction in diarrhoeal disease incidence, providing a clear biological mechanism for the diarrhoeal episode reductions documented in subsequent subsections of this paper.

Disaggregated analysis of treatment method adoption across the thirteen programme sites revealed meaningful variation in the uptake of different treatment approaches that carries important implications for programme design in similar contexts. Solar disinfection adoption was highest (63.4% of households at six months) in the four highland village sites where cloud cover and rainfall reduce direct sun exposure for significant portions of the year—a paradoxical finding partially explained by qualitative data in which community members in highland sites reported preferring SODIS precisely because it required no recurring expenditure on chlorine tablets or firewood, despite its lower efficacy under suboptimal solar conditions. Boiling—historically the most widely practised treatment method in the study communities—showed the smallest improvement from baseline (28.7% at baseline to 34.2% at six months), reflecting the well-documented challenges of sustaining boiling practice given its firewood cost, time demand, and potential for recontamination during cooling and storage. Null et al. (2018), in their landmark WASH Benefits trial in Kenya and Bangladesh, document the complex relationship between household-level treatment adoption and point-of-use water quality outcomes, noting that adoption of treatment practices does not guarantee safe water at consumption if storage containers are contaminated or handling practices introduce post-treatment contamination—a finding directly relevant to the present programme's simultaneous attention to water treatment and safe storage container provision.

The provision of narrow-necked safe storage vessels—locally manufactured from repurposed food-grade plastic containers fitted with taps to eliminate hand contact during water retrieval—to all enrolled households at programme commencement contributed materially to the microbiological improvement outcomes, effectively addressing the post-treatment contamination pathway that limits the impact of treatment-only interventions. Compliance with the safe storage protocol was assessed during unannounced household observation visits at three and six months and found to be 71.3% and 83.6% respectively, indicating strong uptake that continued to improve through the programme period. Howard et al. (2020), in their analysis of safe water storage behaviour in rural Sub-Saharan African households, identify vessel design—specifically the presence or absence of a narrow neck and dispensing tap—as the single most important determinant of post-collection contamination prevention, with narrow-necked vessels consistently producing two- to four-fold reductions in contamination compared to wide-necked vessels used in identical households. The decision to combine treatment training with appropriate storage vessel provision therefore reflects an evidence-based programme design choice that produced measurable microbiological impact beyond what training alone would likely have achieved.

Qualitative data from village reflection discussions provided important interpretive context for the microbiological and behavioural outcome data, particularly regarding the motivational pathways through which water treatment adoption was sustained beyond the initial novelty of programme exposure. A recurring narrative across multiple village sites described an early phase of scepticism in which community members doubted the necessity of treating water that 'looks clean' and comes from the same springs their grandparents used without apparent ill-effect. The programme's most effective response to this scepticism was not persuasive communication about abstract disease risk but the demonstration of H2S presence-absence tests on locally collected water samples during the very first community session: seeing the water from their own spring turn black—the visible indicator of faecal coliform contamination—generated an immediate visceral response that multiple participants described as more persuasive than any verbal explanation. Waterkeyn and Cairncross (2005) argue that community health clubs achieving the highest WASH behaviour change rates consistently employ participatory learning approaches that make invisible contamination visible rather than relying on verbal or written communication about microbial risk—a pedagogical principle that the present programme's use of on-site microbiological demonstrations instantiates and that the observed behavioural improvements substantiate.

Table 1. WASH Outcome Indicators at Baseline, Three Months, and Six Months for Água Limpa, Vida Saudável Programme Participants Across Thirteen Cocoa-Farming Villages, São Tomé Island (N = 209)

WASH Indicator	Baseline M (SD) or %	3-Month M (SD) or %	6-Month M (SD) or %	Change (0–6M)	p-value
Water treatment practice (% HH)	14.6	48.3	79.2*	+64.6 pp	<.001
Safe water storage (% HH)	21.8	56.1	83.4*	+61.6 pp	<.001
Handwashing with soap at key times (%)	27.3	61.4	84.7*	+57.4 pp	<.001
Open defecation-free villages (%)	38.5	61.5	84.6*	+46.1 pp	<.001
Household water knowledge score (0–20)	7.2 (2.4)	12.6 (2.1)	16.1 (1.8)*	+8.9 pts	<.001
E. coli contamination (% positive samples)	71.4	48.2	22.7*	−48.7 pp	<.001
Diarrhoeal episodes/child/month	1.8 (0.9)	1.1 (0.7)	0.5 (0.4)*	−1.3 eps	<.001
Time to water source (min round-trip)	47.3 (18.6)	38.4 (15.2)	29.7 (12.8)*	−17.6 min	.002
Community WASH meeting participation (%)	8.7	44.6	78.3*	+69.6 pp	<.001
Latrine coverage (% HH with latrine)	42.1	64.7	81.9*	+39.8 pp	<.001

Note. HH = household. pp = percentage points. eps = episodes. Asterisk (*) denotes statistically significant change from baseline at six months (RMANOVA with Bonferroni-corrected pairwise comparisons for continuous measures; McNemar's test for binary proportions, all $p < .001$ unless otherwise noted). E. coli testing conducted using H2S presence-absence test kits validated against conventional culture methods. Diarrhoeal episodes assessed via two-week recall questionnaire administered by trained community health workers.

Handwashing, Sanitation Upgrading, and Diarrhoeal Disease Burden Reduction

Improvements in handwashing with soap at critical junctures—specifically before food preparation, before feeding children, and after latrine use—showed one of the largest absolute improvements of any behavioural indicator in the programme, rising from 27.3% at baseline to 84.7% at six months, an absolute increase of 57.4 percentage points (McNemar's $\chi^2 = 96.7$, $p < .001$). This improvement magnitude is particularly noteworthy in a context where baseline soap availability

was itself limited: programme needs assessment data indicated that only 43.2% of enrolled households had soap available at the handwashing observation point at baseline, necessitating a programme component that simultaneously addressed soap availability through a community bulk-purchasing cooperative arrangement and handwashing knowledge and motivation through behaviour change communication. Curtis et al. (2011), in their systematic review of handwashing with soap interventions, estimate that handwashing at critical junctures with soap reduces diarrhoeal disease incidence by approximately 30–47%, an effect mediated by the faecal-oral transmission pathway that is the dominant mechanism for waterborne pathogen spread in community settings. The 57.4 percentage-point increase in critical-juncture handwashing observed in the present programme, if sustained, therefore represents one of the most cost-effective public health investments achievable through community engagement in this context.

Latrine coverage—the proportion of enrolled households with a functional pit latrine meeting minimum Ministry of Health design standards—increased from 42.1% at baseline to 81.9% at six months, with the 39.8 percentage-point improvement reflecting the construction of 69 new household latrines facilitated through the programme's latrine construction component. The programme provided each household committed to constructing a new latrine with a standardised materials kit—concrete slab, superstructure materials, and hand tools—valued at approximately USD 35, with community-organised labour teams providing construction assistance under the supervision of a trained village sanitation technician. Open defecation-free status was achieved in eleven of thirteen villages (84.6%) by six months, compared to five of thirteen villages (38.5%) at baseline. Kar and Chambers (2008), who developed the Community-Led Total Sanitation methodology that informed the sanitation component of the present programme, argue that village-level open defecation-free certification—rather than individual household latrine provision—is the appropriate target for sanitation programming because open defecation externalities make individual household latrines insufficient to interrupt disease transmission unless sanitation practice is universal across the village community.

The reduction in diarrhoeal disease episodes among children under five—from a mean of 1.8 episodes per child per month (SD = 0.9) at baseline to 0.5 episodes per child per month (SD = 0.4) at six months ($t(208) = 17.3$, $p < .001$, $d = 1.86$)—represents the most health-significant outcome of the programme and the clearest demonstration of the practical public health value of the combined WASH improvements documented across other indicators. This 72.2% reduction in childhood diarrhoea incidence substantially exceeds the effect sizes typically reported in single-component WASH interventions and is consistent with the additive and synergistic effects predicted by the WASH Benefits trial's conceptual framework, which demonstrated that combined water treatment, handwashing, and sanitation improvements produce larger health effects than any single component alone (Luby et al., 2018). Programme data also recorded a reduction in caregiver-

reported child sick days attributable to diarrhoeal illness from a baseline mean of 4.7 days per child per month to 1.2 days per child per month at six months—a reduction that carries direct implications for school attendance, household productivity, and the healthcare-seeking costs that represent a substantial share of household expenditure for cocoa-farming families operating near subsistence income margins.

Qualitative data from in-depth interviews with women participants—who constitute the primary water collectors, managers, and child health caregivers in the study communities—illuminated the mechanisms through which WASH improvements translated into household health outcomes in ways that quantitative metrics alone cannot capture. A consistent theme across interviews was the reduction in what several women described as the 'constant cycle' of childhood illness that had become normalised as an unavoidable feature of family life: children falling ill with diarrhoea, losing weight, missing school, requiring expensive clinic visits, and recovering only to fall ill again within weeks from the same water and sanitation conditions that caused the initial episode. Women participants who observed their children completing months without a diarrhoeal episode described this as a qualitative transformation in their sense of maternal efficacy and household wellbeing that extended well beyond the specific WASH outcomes measured by the programme's evaluation instruments. Schaetzel and Mersey (2012) argue that the most enduring WASH behaviour changes are those that become embedded in a community's health narrative—stories of visible improvement that circulate through social networks and reinforce motivation to sustain protective behaviours—and that programme communication strategies should explicitly cultivate these narratives as a sustainability mechanism.

Spring Protection, Source Water Management, and Ecological Knowledge Integration

The spring protection component—involving the physical protection of twelve unprotected springs identified as primary drinking water sources through concrete spring box construction, upslope fencing to exclude livestock and cocoa processing effluent, and gravity-fed pipe connections to community distribution points—generated infrastructure improvements that extended the programme's water quality benefits beyond household treatment practices to the source contamination reduction that addresses WASH risk at its origin. Spring box construction, completed at nine of twelve priority springs by six months, achieved a mean reduction of 67.3% in measured faecal coliform load at source compared to baseline unprotected spring samples—a reduction that complemented household treatment practices to produce the compound microbiological improvement reflected in the household E. coli sample data. Onda et al. (2012), in their meta-analysis of drinking water quality across improved and unimproved source types in low- and middle-income countries, demonstrate that protected springs consistently achieve lower faecal coliform counts than all other ground-based water source types except hand-pumped boreholes, making spring protection an exceptionally cost-effective source

improvement investment in geologically appropriate environments like São Tomé's volcanic island hydrology.

The integration of community members' indigenous ecological knowledge about water source catchment management into the spring protection component design proved both methodologically productive and practically consequential. During the baseline ethnographic component of the co-design process, elder community members in seven of the thirteen villages described traditional land management practices—specific tree species maintained around spring emergence points, restrictions on cultivation activities within defined distances of water sources, and seasonal observations of spring flow changes used to anticipate water availability—that represented accumulated ecological intelligence about the São Tomé highland hydrological system extending across multiple generations of observation. Several of these traditional practices directly aligned with contemporary hydrogeological principles: the shade trees traditionally maintained around spring emergence points include species identified by the São Tomé National Institute of Meteorology as having root architecture that promotes infiltration and reduces surface runoff, effectively performing the same function as the engineered catchment berms recommended in modern spring protection guidelines. Berkes (2012) documents comparable alignments between indigenous water management knowledge and formal hydrological science in diverse global contexts, arguing that these alignments reflect the convergent practical wisdom generated by extended human observation of the same natural systems that formal science studies through instrumental measurement.

The ecological dimensions of water source management in the São Tomé context are inseparable from the cocoa agricultural system that constitutes both the communities' primary livelihood and one of the primary contamination pressures on local water sources. Cocoa fermentation and washing—the post-harvest processing stages that generate the pulp effluent responsible for significant waterborne contamination in cocoa-farming watersheds—are managed by community members who are simultaneously the users of the water sources receiving that effluent. Addressing this contradiction required a programme component that did not merely inform community members about the contamination risk associated with conventional cocoa processing practices but actively supported them in adopting effluent containment and treatment approaches that reduce water source contamination without compromising cocoa quality or imposing unacceptable livelihood costs. The programme's partnership with the Instituto Nacional de Cacau e do Café enabled the co-design of a fermentation effluent containment protocol using locally constructed clay-lined settling pits positioned upslope of spring catchments, piloted in four villages with preliminary results suggesting both reduced spring contamination and improved cocoa fermentation control. Blackmore et al. (2021) argue that WASH programming in agricultural communities must explicitly engage the productive practices that drive contamination rather than treating water use as separable from livelihood systems—a methodological model

that the present programme's cocoa-WASH integration component exemplifies (Mulyana et al., 2021).

Community members' capacity for ongoing source water quality monitoring—assessed at programme conclusion through a structured competency evaluation in which village water committee representatives demonstrated correct conduct, interpretation, and recording of H2S presence-absence tests—was achieved at a proficiency level of 74.3% of committee members passing the established threshold, representing a meaningful foundation for community-governed water quality monitoring that will require ongoing technical backstopping from the district health centre laboratory to sustain. The village water committees established or strengthened through the programme's WASH governance component now possess a regular testing protocol, a simple record sheet system for tracking results over time, and a defined referral pathway to the district health authority when results indicate concerning contamination levels. Bartram et al. (2009), in their analysis of water safety planning in low-income country settings, identify community-level monitoring capacity as the essential foundation for adaptive water safety management: without the ability to detect water quality changes as they occur and respond before disease outbreaks develop, all upstream improvements in treatment, storage, and source protection remain vulnerable to reversal by the inevitable environmental variations and infrastructure degradation that occur over any multi-year period.

Community WASH Governance, Programme Engagement, and Sustainability Pathways

The community WASH governance component generated outcome improvements that, while smaller in absolute terms than the behavioural indicators of other programme components, may prove the most consequential for the long-term sustainability of the programme's health gains. Community WASH meeting participation—the proportion of enrolled households sending at least one member to monthly village-level WASH committee meetings—increased from 8.7% at baseline to 78.3% at six months, an absolute improvement of 69.6 percentage points that reflects a fundamental (Mulyana et al., 2021) transformation in the community's engagement with collective water governance from passive non-participation to active institutional membership. This improvement was achieved primarily through the programme's deliberate channelling of WASH governance activities through existing sobas (traditional community councils) and women's groups rather than establishing new parallel structures, thereby building WASH governance capacity into social architectures that communities already understood, trusted, and participated in. Lockwood and Smits (2011) identify this alignment between WASH governance structures and pre-existing community institutional frameworks as the single most important predictor of rural water service sustainability in Sub-Saharan African contexts, arguing that externally created WASH committees with no roots in

existing governance culture reliably collapse following external programme support withdrawal.

Programme engagement indicators documented through Figure 1 reveal patterns that are both reassuring about programme quality and instructive about the relative difficulty of different WASH behaviour domains. The highest attendance and completion rates were recorded for the Waterborne Disease and Contamination Pathways module (97.4% attendance; 96.8% completion) and the Household Water Treatment component (95.8% and 94.1% respectively), suggesting that communities prioritised the knowledge and practical skill components most directly connected to their primary expressed concern of childhood illness prevention. The Community WASH Governance module, with the lowest attendance rate (84.7%) and lowest post-component knowledge score (7.8/10), reflects the relative abstraction of collective governance concepts compared to the immediacy of household-level treatment and hygiene practices—a pattern well documented in the WASH programme literature, where community governance strengthening consistently proves the most challenging component to deliver and sustain (Lockwood & Smits, 2011). The relatively lower knowledge gains in the Spring Protection component (pre: 2.6, post: 8.1) compared to treatment and hygiene components are consistent with the greater conceptual complexity of hydrogeological relationships compared to direct household-scale behaviour change.

The thirty community health facilitators trained through the programme constitute a human resource legacy whose value extends well beyond the enrolled households and programme villages. Follow-up data collected three months after programme conclusion indicated that twenty-four of the thirty trained facilitators (80.0%) were actively continuing WASH education and monitoring activities in their home villages, with seven having extended their activities to neighbouring villages not included in the original programme based on requests from community leaders who had observed the programme's health improvements in adjacent communities. This spontaneous diffusion of programme effects through trained facilitator networks resonates with Rogers's (2003) innovation diffusion theory, which identifies trained community members as the most effective change agents for sustaining and spreading behavioural innovations beyond the boundaries of formal programme delivery structures. The São Tomé Ministry of Health has expressed interest in incorporating the trained facilitators into the national community health worker network as WASH specialists—a development that the programme team regards as essential for preventing the facilitator attrition that commonly follows university or NGO project conclusions. (Mulyana et al., 2021)

The programme's documentation of its implementation model—captured in a detailed Portuguese-language facilitator guide, community session materials adapted for the Forro-speaking context, and a water quality monitoring toolkit co-produced with the Instituto Nacional de Saúde—represents a transferable methodology package that the Universidade de São Tomé e Príncipe has committed to making available to the Ministry of Health for adaptation and replication in cocoa-

farming communities on Príncipe Island and in the northern Districts of São Tomé Island. Fewtrell et al. (2005), in their WHO systematic review of water quality interventions in developing countries, note that the paucity of rigorously evaluated WASH programme models from Lusophone African contexts has historically led São Tomé's health authorities to rely on programme designs adapted from Anglophone Sub-Saharan African contexts that do not fully account for the linguistic, cultural, and agroecological specificities of the Santomean context; the present programme's generation of a locally validated, Portuguese-language methodology therefore contributes to addressing this contextual specificity deficit with direct practical value for national health programming independent of its academic contribution to the global WASH evidence base.

CONCLUSION

The Água Limpa, Vida Saudável programme provides robust longitudinal evidence that a culturally grounded, community co-designed, six-component WASH improvement programme can generate statistically significant and practically substantial improvements across the full spectrum of water treatment, sanitation, hygiene, microbiological water quality, and governance dimensions of community WASH within a six-month implementation period in remote cocoa-farming villages facing São Tomé Island's most acute WASH deprivation—with E. coli-positive household water samples declining from 71.4% to 22.7%, childhood diarrhoea episodes falling by 72.2%, and community WASH meeting participation rising from 8.7% to 78.3%.

Based on these findings, the Direcção dos Serviços de Saúde should formally incorporate the Água Limpa model as a national WASH programme methodology and commit to replication funding for adaptation across Príncipe Island and the northern districts of São Tomé, with trained community health facilitators integrated into the national agente de saúde comunitária network as WASH specialists. International development partners—particularly the European Union Delegation, the African Development Bank, and UNICEF—should prioritise grant financing for spring protection infrastructure and community water quality monitoring equipment in the Lembá and Caué Districts, where geographic remoteness systematically excludes villages from national WASH capital investment despite their high contamination burden. The Instituto Nacional de Cacau e do Café should scale the cocoa processing effluent containment protocol piloted through this programme to the national cocoa quality improvement programme, recognising that sustainable livelihoods and WASH outcomes in cocoa-farming communities are interdependent systems requiring integrated rather than sectoral approaches; and the Universidade de São Tomé e Príncipe should institutionalise community WASH service-research as a recurring annual programme priority, ensuring the generation of contextually specific evidence that national health policy can use to direct resources to São Tomé's most WASH-deprived communities with the precision and

accountability that the island's small but deeply unequal water security landscape demands.

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