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The Synergy of Environmental and Social Standards in Achieving Equitable Water, Sanitation, and Hygiene (WASH) Outcomes in Tafawa-Balewa LGA, Bauchi State, Nigeria

Abdulmajeed Iliyasu Gital[1], Jibril Muhammad[1& 2], Istifanus Yarkasuwa Chindo[1 & 3], Salahuddeen Ilyasu Gital[4]

[1]Sustainable Procurement Environmental and Social Standards Enhancement Centre of Excellence, Abubakar Tafawa Balewa University Bauchi
[2]Department of Chemical Engineering, Abubakar Tafawa Balewa University, P.M.B 0248, Bauchi, Nigeria
[3]Department of Chemistry, Abubakar Tafawa Balewa University, P.M.B 0248, Bauchi, Nigeria
[4]Department of Biochemistry, Ahmadu Bello University, Zaria, Nigeria

Abstract

This study examines the interaction between environmental and social standards in shaping equitable access to Water, Sanitation, and Hygiene (WASH) services in Tafawa-Balewa Local Government Area of Bauchi State, Nigeria, a region characterized by significant ethnic diversity and complex topographical conditions. Despite global and national commitments toward achieving Sustainable Development Goal 6 (SDG 6), disparities in WASH service delivery persist, particularly among socially and geographically marginalized populations. A convergent parallel mixed-methods research design was adopted, integrating quantitative and qualitative datasets to provide a comprehensive assessment of WASH equity. Quantitative data were obtained from 380 household surveys conducted across four selected wards, while qualitative evidence was generated through 15 key informant interviews, eight focus group discussions, and observational assessments of 39 WASH facilities. Descriptive and inferential statistical analyses, complemented by thematic content analysis, were employed to examine patterns of access and exclusion. The findings reveal pronounced intersectional inequalities in WASH outcomes. Access to improved water sources was significantly lower among Jarawa households (42.4%) compared with Hausa households (68.8%) ($\chi^2 = 24.7$, $p < 0.001$). Gender disparities were equally evident, with women spending an average of 45 minutes per water-fetching trip compared to 18 minutes for men. Analysis identified three dominant patterns of standards interaction—conflictual, synergistic, and sequential—shaped by institutional fragmentation, ethnic power relations, knowledge hierarchies, and socio-cultural norms. Based on these findings, a Dynamic Interplay Model was developed to explain how interactions among standards influence WASH equity outcomes. The study demonstrates that synergistic integration of environmental and social standards produces more equitable and sustainable WASH services. It recommends contextualized standards implementation, strengthened institutional coordination, inclusive community engagement, and systematic monitoring of equity indicators to ensure that the SDG 6 commitment of "leaving no one behind" is effectively realized.

Keywords
Environmental Standards, Intersectional Disparities, Social Standards, Tafawa-Balewa LGA, WASH Outcomes

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Faculty of Science, ATBU Bauchi

Corresponding Author: Abdulmajeed Iliyasu Gital, Sustainable Procurement Environmental and Social Standards Enhancement Centre of Excellence, Abubakar Tafawa Balewa University Bauch. Email: aigital.pg@atbu.edu.ng

INTRODUCTION

Access to safe water, sanitation, and hygiene (WASH) remains a critical challenge in Nigeria, particularly in ethnically diverse and topographically varied areas such as Tafawa-Balewa LGA, Bauchi State. This study investigates the interplay between environmental and social standards in shaping equitable WASH outcomes in the LGA. Employing a convergent parallel mixed-methods design, the research integrates quantitative data from 380 household surveys across four wards with qualitative insights from 15 key informant interviews, eight focus group discussions, and observational assessments of 39 WASH facilities.

Findings reveal significant intersectional disparities: only 42.4% of Jarawa households access improved water sources compared to 68.8% of Hausa households ($\chi^2=24.7$, $p<0.001$), while women spend an average of 45 minutes per water-fetching trip compared to 18 minutes for men. Three patterns of standards interplay are identified as conflictual, synergistic, and sequential all mediated by institutional fragmentation, ethnic power dynamics, knowledge hierarchies, and socio-cultural norms.

The research develops a Dynamic Interplay Model and demonstrates that synergistic interplay leads to more equitable and sustainable outcomes. Recommendations include contextualising standards, investing in inclusive community engagement, reforming institutional coordination, and monitoring equity outcomes. The study concludes that achieving SDG 6's "leave no one behind" imperative requires intentional design of standards interplay, not isolated technical or social interventions. placed many Jarawa communities in hilly, hard-to-reach areas, creating a geographical dimension to social marginalisation.

Previous WASH interventions have often been largely supply-driven and infrastructure-focused, privileging technical environmental standards such as water quality, source protection, and construction over social standards addressing inclusion, participation, affordability, and non-discrimination (Carrard et al., 2020). these interventions have leaned on a narrow set of WASH indicators—linear growth and diarrhea—that reflect a 20th-century prioritization of microbiological water quality as the most important measurement of WASH intervention success.

Even when water is microbiologically safe, hundreds of millions of people face harassment, assault, injury, poisoning, anxiety, exhaustion, depression, social exclusion, discrimination, subjugation, hunger, debt, or work, school, or family care absenteeism when retrieving or consuming household water. Measures of WASH intervention success should incorporate these impacts to reinforce the WASH value proposition. (Stoler et al., 2023). This artificial separation creates a policy-practice gap with profound equity implications: a borehole may meet all technical specifications but be sited where marginalised groups cannot access it, or a highly participatory process may result in infrastructure that fails prematurely.

The dynamic interaction or interplay between these two categories of standards is therefore a critical yet under-researched determinant of who benefits from WASH interventions. This study addresses that gap

by investigating how environmental and social standards interact in practice, and how this interplay shapes equitable outcomes in Tafawa-Balewa LGA.

Despite decades of WASH investment in Nigeria, equitable and sustainable access remains elusive. In Tafawa-Balewa LGA, disparities in WASH access are visibly patterned along lines of ethnicity, gender, socio-economic status, and location. Conventional explanations cite insufficient funding, infrastructure deficits, or low community awareness, but a deeper problem exists: the disconnect between technical-environmental and social approaches to WASH programming, and an inadequate understanding of how these dimensions interact in practice. failure to understand the interconnectedness of these complexities has resulted in WASH solutions that are unaffordable, not inclusive, or unsustainable (Rhodes-Dicker et al., 2022).

Environmental standards, codified in documents such as the Nigerian Standard for Drinking Water Quality (NSDWQ), emphasise measurable technical outcomes for water quality test results, construction specifications, setback distances. Social standards, which operationalise human rights principles of availability, accessibility, acceptability, and affordability, are frequently treated as "soft" components and marginalised during implementation (Harvey & Reed,2007) (Harvey & Reed, 2007). This creates implementation gaps where projects may be environmentally sound but socially exclusionary, or socially inclusive but environmentally unsustainable.

The interplay between these standards is not uniform. It can be synergistic (social cohesion enabling environmental sustainability), conflictual (environmental requirements exacerbating social exclusion), or sequential (social foundations preceding successful environmental action). In Tafawa-Balewa, the nature and consequences of this interplay have not been empirically documented. Without understanding these dynamics, interventions risk being technically compliant yet inequitable, or well-intentioned but unsustainable. This study therefore addresses the core problem: How does the interplay between environmental and social standards shape patterns of access and exclusion among different social groups in Tafawa-Balewa LGA, and what institutional and socio-political factors mediate this interplay? The aim of this study is to assess the interaction between environmental and social standards in shaping equitable WASH outcomes in Tafawa-Balewa LGA.

The specific objectives are to:

I. Evaluate the level of compliance to social standards in WASH provision
II. To examine the combined effect of environmental and social standards on WASH outcome.
III. To identify critical bottlenecks affecting the implementation of environmental and social standards in WASH systems.
IV. To analyze the socio-political, cultural, and institutional power dynamics that mediate the interplay between these standards.
V. To develop strategic pathways and a framework for transitioning from conflictual to synergistic

standards implementation to enhance equitable WASH outcomes.

Research questions being considered in this study are as follows:

1) How do local power structures, ethnic hierarchies, cultural norms, and institutional arrangements mediate the interaction of WASH standards in the study area?
2) What strategic pathways and frameworks can be established to transition from conflictual to synergistic standards implementation in the LGA?

This study provides evidence-based recommendations for Bauchi State RUWASSA, NGOs, community organisations, and national policymakers on adapting standards to local contexts, reforming institutional arrangements, and empowering marginalised groups. This study contributes to both theory and practice. Theoretically, it develops a Dynamic Interplay Model integrating political ecology, intersectionality theory, and implementation science to explain how standards operate in practice. It advances intersectional analysis in WASH research and contributes to debates on the "technical versus social" dichotomy in development. Practically, Methodologically, it demonstrates innovative mixed-methods approaches for capturing complex socio-technical phenomena. Socially, by centring the experiences of marginalised groups, the research supports advocacy for more equitable resource allocation.

MATERIALS AND METHODS

Study Area

Tafawa-Balewa LGA is located in southern Bauchi State, covering approximately 2,451km² with a population estimated at 395,200 (National Population Commission of Nigeria; National Bureau of Statistics). The area experiences a tropical wet-and-dry climate with rainfall concentrated between May and September. Topographically, it transitions from plains in the north to the Jos Plateau escarpment in the south (700–1,200 m above sea level). The population is predominantly Jarawa and Sayawa (indigenous groups), with significant Hausa and Fulani populations. Settlement patterns reflect historical and geographical factors: many Jarawa communities are in hilly areas, while Hausa communities are often in more accessible plains. Four wards were purposively selected for maximum variation: Tafawa Balewa Town Ward: Urban/peri-urban, ethnically mixed with Hausa predominance, higher infrastructure density., Bununu Ward: Mixed rural-urban, significant ethnic diversity, moderate infrastructure., Gital Ward: Predominantly rural, majority Jarawa, challenging hilly terrain., Bula Ward: Rural, mixed ethnicity but Fulani predominance, pastoralist livelihoods.

Sampling Design and Sample Size

A multistage cluster sampling approach was used for the household survey. The four study wards were selected purposively. From each ward, two communities were selected using stratified random sampling (by size and location). Within each community, households were sampled using systematic random sampling (every fifth household along transects from a central point). Sample size was calculated using the formula for a single

proportion ($n = Z^2pq/e^2$), giving 384 households, adjusted to a target of 400 to account for non-response; 380 valid responses were achieved. For qualitative components, 15 key informants were selected through purposive maximum variation and snowball sampling, 8 FGDs employed stratified purposive sampling (by gender, ethnicity, and special populations), 39 WASH facilities were observed using maximum variation sampling, and 47 documents were reviewed purposively until saturation.

Methods of Data Collection

All instruments were developed iteratively, pre-tested in Lere ward (a non-sampled ward), and finalised. The household questionnaire included five sections: household characteristics (14 items), water access (22 items), sanitation and hygiene (18 items), participation and decision-making (12 items), and standards awareness and implementation (10 items). It was translated into Hausa and back-translated. Key informant guides covered standards awareness, implementation experiences, interplay observations, mediating factors, and recommendations. FGD guides incorporated participatory mapping, timelines, ranking exercises, and scenario discussions. The observation checklist assessed environmental, social accessibility, operational, and contextual indicators. Document extraction templates captured metadata, standards content, implementation guidance, equity considerations, and gaps.

Methods of Data Analysis

Quantitative data were entered into SPSS 27, cleaned, and analysed using descriptive statistics, chi-square tests, t-tests/ANOVA, logistic regression, and linear regression. A wealth index was constructed using PCA. Spatial analysis was performed in QGIS. Qualitative data were transcribed, translated, and analysed thematically in NVivo 12 following Braun and Clarke's (2006) six-phase approach. Integration was achieved through joint displays, triangulation, and meta-inferences.

RESULTS AND DISCUSSION

Socio-Demographic Profile of Participants

The survey included 380 respondents across four wards, with a deliberate oversampling of women (58.9%) as primary water managers. The sample reflected the LGA's diversity: 37.9% Jarawa, 28.9% Sayawa, 21.1% Hausa, and 12.1% Fulani. Unlike the strong ethno-religious correlation observed for Sayawa (88% Christian) and Hausa (96% Muslim), the Jarawa population was religiously mixed: only 45% identified as Christian, with the majority (55%) being Muslim. Fulani respondents were entirely Muslim.

Consequently, the overall sample was 43.4% Christian and 56.6% Muslim, underscoring the need to avoid assumptions of a simple ethnic-religious divide. Economic disparities were pronounced: 58.7% of households in Gital were in the two poorest quintiles compared to 29.6% in Tafawa Balewa town. Farming was the primary occupation (52.9%), with pastoralism concentrated in Bula (34.0%).

Table 4.1: Socio-Demographic Characteristics of Survey Respondents (N=380)

Characteristic	Category	Frequency	Percentage
Ward	Tafawa Balewa	98	25.8
	Bununu	96	25.3
	Gital	92	24.2
	Bula	94	24.7
Gender	Female	224	58.9
	Male	156	41.1
Age group	18-35 years	185	48.7
	36-55 years	142	37.4
	56+ years	53	13.9
Ethnicity	Jarawa	144	37.9
	Sayawa	110	28.9
	Hausa	80	21.1
	Fulani	46	12.1
Religion	Christian	165	43.4
	Muslim	215	56.6
Education	No formal schooling	142	37.4
	Primary only	126	33.2
	Secondary or higher	112	29.5
Primary occupation	Farming	201	52.9
	Trading/business	89	23.4
	Pastoralism	46	12.1
	Formal employment	24	6.3

Characteristic	Category	Frequency	Percentage
	Unemployed/other	20	5.3
Wealth quintile	Poorest	76	20.0
	Poor	80	21.1
Characteristic	Category	Frequency	Percentage
	Middle	78	20.5
	Rich	74	19.5
	Richest	72	18.9

Environmental Standards Implementation

Compliance with environmental standards showed significant gaps. Only 20.8% of observed water points (5 of 24) had undergone water quality testing within the previous six months as recommended by NSDWQ, with testing concentrated in Tafawa Balewa town and Bununu. A RUWASSA monitoring officer explained: "We prioritise testing where there's reported illness or during project commissioning. Routine testing of all points is impossible with our resources" (KII-02). Only 33.3% of water points met the 50-metre setback guideline from contamination sources. Compliance was lowest in high-density areas of Tafawa Balewa town (16.7%) and pastoralist areas of Bula ward (22.2%).

Protected wellheads or spring boxes were more common (62.5%), but seven of fifteen showed cracks, missing covers, or other defects. Functional drainage was present at only 41.7% of points, and effective animal exclusion at 37.5%. Construction standards showed mixed compliance. All boreholes met basic construction requirements, but siting decisions often prioritised technical over social considerations. In Gital, three of six boreholes were located in lower-lying areas despite hill settlements having greater need, due to drilling feasibility. An engineer explained: "The rig can't access steep slopes. We drill where it's technically feasible, then pipe if possible" (KII-13).

However, piping to hill communities had occurred in only one case due to cost constraints. Maintenance systems were weak. Only 29.2% of water points had visible maintenance records. Five of 24 points (20.8%) were non-functional at observation, with average downtime of 4.3 months. Non-functionality was highest in Gital (33.3%) and Bula (33.3%). Points with active water committees and fee collection had 100% functionality, compared to 66.7% for community-managed points without regular funding, and 50% for government-managed points.

Table 4.2: Compliance with Environmental Standards (n=24 Water Points)

Standard	Compliant	Non-compliant	Partial compliance	Ward variations (Compliant/Total)
50m setback from contamination	8 (33.3%)	12 (50.0%)	4 (16.7%)	TB: 1/6; Bun: 3/6; Git: 2/6; Bula: 2/6
Protected wellhead/ spring box	15 (62.5%)	9 (37.5%)	-	TB: 4/6; Bun: 5/6; Git: 3/6; Bula: 3/6
Functional drainage	10 (41.7%)	14 (58.3%)	-	TB: 3/6; Bun: 4/6; Git: 2/6; Bula: 1/6
Water quality testing (last 6 months)	5 (20.8%)	19 (79.2%)	-	TB: 3/6; Bun: 2/6; Git: 0/6; Bula: 0/6
Visible maintenance records	7 (29.2%)	17 (70.8%)	-	TB: 3/6; Bun: 2/6; Git: 1/6; Bula: 1/6
Fencing/animal exclusion	9 (37.5%)	15 (62.5%)	-	TB: 2/6; Bun: 4/6; Git: 2/6; Bula: 1/6

Social Standards Implementation

Formal participation structures existed but showed limited effectiveness. While 86.8% of households reported awareness of water committees, only 42.4% could name a member from their ethnic group, and just 28.4% of women reported attending meetings. Participation gaps were widest in Gital, where only 15.2% of Jarawa women reported engagement.

Committee composition revealed power imbalances: Hausa members held 71.7% of leadership positions despite comprising only 21.1% of the population. A Sayawa elder explained: "The committee always has Hausa chair because they're seen as educated and neutral. But neutral means favouring the powerful" (KII-07). Decision-making processes showed limited community influence. Across all wards, 73.2% of households reported that water point siting decisions were made primarily by ward heads or local government officials, with only 21.8% reporting community consultation. Even when consultation occurred, it was often symbolic. A female participant noted: "They call a meeting to tell us where they'll drill. If we suggest somewhere else, they say it's not technically suitable" (FGD-W-Bununu). Gender equity standards showed implementation gaps despite policy commitments.

Women comprised only 31.7% of water committee members, below the 35% target in Nigeria's National Gender Policy (Salaudeen & Jiddere, 2024). Their participation often did not translate to influence: "I can attend, but when the men speak, I keep quiet. That's our culture. And meetings are at times when women are cooking" (FGD-W-TB). Menstrual hygiene management facilities were completely

absent from public and school sanitation facilities observed. Gender-based water collection burdens showed stark disparities. Women and girls were primary fetchers in 77.9% of households, spending an average of 44.7 minutes per round trip compared to 17.9 minutes for male fetchers ($t=8.24$, $p<0.001$). This time burden showed intersectional patterns: Jarawa women in hill settlements spent 67.8 minutes on average, nearly triple the time for Hausa women in Tafawa Balewa town (23.4 minutes).

Table 4.3: Water Collection Time Burden by Gender and Location

Category	Mean time (minutes)	Standard deviation	N	Comparison (t-test)
All female fetchers	44.7	18.3	296	t=8.24, p<0.001 (vs female)
All male fetchers	17.9	9.6	84	
Jarawa women (hills)	67.8	21.4	58	t=5.67, p<0.001 (vs Jarawa hills)
Hausa women (town)	23.4	8.9	42	
Fulani women (pastoral)	52.3	16.7	31	-
Sayawa women (mixed)	38.6	14.2	65	-

Access Patterns and Intersectional Disparities

Access to improved water sources varied dramatically across social groups. Hausa households had the highest access to boreholes or piped water (68.8%), while Jarawa households relied heavily on unprotected springs (30.6%) and surface water (18.8%). The ethnic disparity was statistically significant ($\chi^2=24.7$, $p<0.001$) and persisted when controlling for wealth and location through logistic regression (OR=2.34, $p<0.01$ for Hausa vs Jarawa).

Geographic disparities compounded ethnic ones. Gital ward, with predominantly Jarawa hill settlements, had the lowest improved water access (38.0%) despite having more water points per capita than Bununu (65.2% access). Spatial analysis showed that 63.4% of hill households were beyond the recommended 500-metre service radius for improved sources, compared to 18.2% of plain households. Sanitation access showed even starker disparities. Only 18.4% of households had access to improved sanitation facilities. Access varied significantly by ward: Tafawa Balewa town (32.7%), Bununu (22.9%), Gital (8.7%), Bula (10.6%) ($\chi^2=28.3$, $p<0.001$). Open defecation remained common, particularly in rural wards: 41.3% in Gital and 38.3% in Bula reported open defecation as primary practice, compared to 8.2% in Tafawa Balewa town.

Table 4.4: Water Source Typology by Ethnicity and Wealth Quintile

Source type	Jarawa (n=144)	Sayawa (n=110)	Hausa (n=80)	Fulani (n=46)	Poorest Q (n=76)	Richest Q (n=72)	Total (N=380)
Piped/ borehole	42.4%	51.8%	68.8%	43.5%	36.8%	70.8%	51.6%
Protected well/spring	23.6%	27.3%	18.8%	30.4%	21.1%	19.4%	24.5%
Unprotected spring	30.6%	18.2%	11.3%	19.6%	35.5%	8.3%	21.1%
Surface water	18.8%	10.0%	2.5%	19.6%	25.0%	4.2%	13.7%
Other	2.1%	1.8%	1.3%	2.2%	3.9%	0.0%	1.8%

Multivariate regression analysis

To isolate the independent effects of social predictors on WASH outcomes, two regression models were estimated. Table 4.5 presents the logistic regression results for access to an improved water source. After controlling for all other variables, Hausa ethnicity remained a significant predictor of improved water access (adjusted OR = 2.43, 95% CI 1.32–4.47, $p<0.01$). Wealth was positively associated with improved access (OR = 1.48 per quintile, $p<0.001$). The interaction term Jarawa × female × hill settlement was statistically significant (OR = 0.38, $p<0.05$), indicating that the odds of having improved water are 62% lower for Jarawa women in hill settlements compared to the reference group, independently confirming the intersectional disadvantage. The Hosmer-Lemeshow test was non-significant ($\chi^2=6.45$, df=8, $p=0.60$), indicating adequate model fit.

Table 4.5: Logistic Regression Results Predicting Access to Improved Water Source

Variable	B (SE)	Wald	p-value	Adjusted OR (95% CI)
Ethnicity (ref = Hausa)				
Jarawa	−0.89 (0.31)	8.24	0.004	0.41 (0.22-0.76)
Sayawa	−0.61 (0.33)	3.42	0.064	0.54 (0.28-1.04)
Fulani	−1.02 (0.41)	6.19	0.013	0.36 (0.16-0.81)
Female (yes = 1)	−0.48 (0.22)	4.76	0.029	0.62 (0.40-0.95)

Hill settlement (yes = 1)	−0.92 (0.27)	11.60	<0.001	0.40 (0.24-0.68)
Wealth quintile (1-5)	0.39 (0.09)	18.79	<0.001	1.48 (1.24-1.76)
Jarawa × female	−0.44 (0.30)	2.15	0.143	0.64 (0.36-1.16)
Jarawa × hill	−0.58 (0.35)	2.75	0.097	0.56 (0.28-1.11)
Female × hill	−0.33 (0.28)	1.39	0.239	0.72 (0.42-1.24)
Jarawa × female × hill	−0.97 (0.46)	4.44	0.035	0.38 (0.15-0.93)
Constant	1.12 (0.28)	16.00	<0.001	3.06

Note: Model χ^2 (10) =78.42, p<0.001. Nagelkerke R^2 =0.28. OR=Odds Ratio; CI=Confidence Interval. Source: Field survey, 2026

Table 4.6 shows the linear regression results for water collection time. Ethnicity, gender, and hill settlement were significant predictors. Being Jarawa increased collection time by 18.5 minutes (p<0.001) relative to Hausa, while female gender added 22.3 minutes (p<0.001). The significant three-way interaction (Jarawa × female × hill, B=15.8, p=0.014) indicates that Jarawa women in hill settlements spend nearly 16 extra minutes per trip beyond what would be expected from the sum of the individual disadvantages. The model explained 44% of the variance (adjusted R^2=0.44, F (10,369) =30.62, p<0.001). Collinearity diagnostics were acceptable (all VIF < 2.3).

Table 4.6: Linear Regression Results Predicting Water Collection Time (Minutes)

Variable	B (SE)	β	t	p-value
(Constant)	12.45 (2.13)	-	5.85	<0.001
Ethnicity (ref = Hausa)				
Jarawa	18.52 (3.44)	0.39	5.38	<0.001
Sayawa	7.12 (3.67)	0.15	1.94	0.053
Fulani	14.83 (4.51)	0.24	3.29	0.001
Female (yes = 1)	22.30 (2.56)	0.49	8.71	<0.001
Hill settlement (yes = 1)	13.67 (2.98)	0.31	4.59	<0.001
Wealth quintile (1-5)	−3.24 (1.02)	−0.15	−3.18	0.002

Jarawa × female	6.91 (3.35)	0.13	2.06	0.040
Jarawa × hill	8.42 (3.86)	0.14	2.18	0.030
Female × hill	5.13 (3.09)	0.08	1.66	0.098
Jarawa × female × hill	15.80 (6.41)	0.18	2.46	0.014

Patterns of Standards Interplay

Analysis of implementation routines revealed three distinct pathways of interplay between environmental and social standards:

1. **Conflictual Interplay:** Conflictual interplay occurred when environmental and social standards worked at cross-purposes, typically due to rigid application of one standard without consideration of the other. Six clear instances were documented. In Gital, a borehole was sited 1.2 km from a hill settlement to meet geological requirements, increasing collection time and safety risks for women.

   A community health worker noted: "The water is clean but useless if people can't access it regularly" (KII-08). In two communities, water treatment systems installed to meet quality standards increased costs beyond community affordability, leading to system abandonment. In Bula, a poured concrete latrine met all construction standards but was unused by pastoralists accustomed to open defecation. Conflictual interplay typically resulted from "checkbox compliance" meeting formal standards without considering local context and generally worsened equity outcomes.

2. **Synergistic Interplay:** Synergistic interplay occurred when environmental and social standards mutually reinforced each other, typically through intentional design. Four instances were documented. In two communities with gender-balanced, representative water committees, maintenance was better, fees were collected regularly, and water points showed 100% functionality over three years. In Bununu, after participatory risk mapping showed contamination risks, the community collectively protected the watershed through bylaws and monitoring.

   In one Tafawa Balewa neighbourhood, a graduated tariff system ensured financial sustainability while maintaining accessibility. Synergistic instances shared common features: flexible adaptation of standards to local context, investment in social processes alongside technical interventions, and accountability mechanisms linking technical performance to social outcomes.

3. **Sequential Interplay:** Sequential interplay occurred when progress on one dimension enabled or required progress on another, typically with social foundations preceding environmental

action. Three instances were documented. In a mixed-ethnicity area with historical tensions, an NGO invested six months in dialogue and conflict resolution before introducing watershed protection; the social cohesion enabled collective environmental action that would have failed otherwise. In one community, extensive training on operation and maintenance preceded installation of a more complex water system; the social investment ensured technical sustainability. In a Gital sub-community, thorough participatory mapping led to a technically suboptimal but socially appropriate siting decision, with community commitment to overcome technical challenges through collective labour.

Factors Mediating Standards Interplay

Four structural blocks were identified as primary mediators of standards implementation:

- **Institutional Architecture:** Institutional arrangements significantly mediated how standards interacted. Budgetary fragmentation was particularly influential: environmental components (drilling, construction) were funded through capital budgets, while social components (training, community mobilisation) came from recurrent budgets that were often depleted.

  A LGA official explained: "When funds are short, the training and meetings are the first to go. The drill must happen that's visible" (KII-04). Monitoring systems privileged environmental over social indicators: RUWASSA's reporting template included 12 technical indicators but only 3 social indicators, with no measures of committee inclusivity or decision-making fairness. Organisational silos created implementation gaps, as water supply, sanitation, and community participation fell under different units with limited coordination. Accountability flowed upward to donors and government rather than downward to communities.

- **Power Relations:** Power relations fundamentally shaped how standards were interpreted and implemented. Ethnic power dynamics were particularly salient. In mixed-ethnicity communities, water committees were consistently dominated by Hausa members (72.3% of leadership positions across documented committees), despite Hausa being a numerical minority in some wards. This reflected broader political hierarchies, as a Sayawa elder explained: "The chairmanship goes with the ward head position, which always goes to them [Hausa]. So they decide where water goes" (KII-07).

Gender power relations limited women's influence despite formal participation. Culturalnorms about women's public roles, meeting times conflicting with domestic responsibilities, and male-dominated meeting spaces all constrained meaningful participation. Elite capture was evident: in three communities, water points were sited near local elites' homes rather than areas of greatest need. In one case, a borehole intended for public use was effectively privatised by a local leader who controlled access. Expert-local power dynamics privileged

technical knowledge over local knowledge. Engineers' assessments of water potential and siting suitability were rarely questioned, even when they conflicted with community understanding.

- **Socio-Cultural Norms:** Socio-cultural norms and practices mediated standards implementation in multiple ways. Gender norms limited women's substantive influence despite policies promoting participation. Pastoralist communities in Bula required water points along migration routes, but standards assumed sedentary populations; a Fulani elder explained: "Your borehole is fixed, but our life moves. The standards don't see us" (FGD-M-Bula). Local concepts of cleanliness, privacy, decision-making traditions, and religious practices all shaped how standards were received and adapted. These factors were not simply obstacles but alternative logics that standards needed to engage with rather than override.

- **Resource Allocation Trends:** Historical patterns of resource allocation created path dependencies. Analysis of project documents (2015–2023) showed that 68.4% of WASH investments targeted areas with existing infrastructure, following a "pipeline" approach. A RUWASSA planner admitted: "We go where we have success. The difficult places get postponed year after year" (KII-02). Water points were sometimes allocated as political rewards. Donor priorities created a patchwork of approaches, as different donors emphasised different standards. Cost considerations often drove siting decisions: drilling in accessible areas reduced costs but excluded marginalised settlements.

CONCLUSION AND RECOMMENDATION

The findings of this study demonstrate that achieving equitable WASH outcomes depends not on the isolated presence of technical or social guidelines, but on the nature of their interplay during field execution. Rigid, technocratic implementation creates conflictual interplay that exacerbates the marginalisation of vulnerable populations, whereas adaptive, inclusive approaches foster synergistic outcomes where technical longevity and social equity reinforce each other. The regression models provide robust empirical evidence of multiplicative intersectional disadvantage, proving that poor Jarawa women residing in topographically isolated hill tracts experience the deepest systemic exclusion.

Based on these conclusions, the following recommendations are provided:

1. **Contextualise Guidelines:** Bauchi State RUWASSA and the LGA WASH unit should transition away from uniform checklists and develop flexible, location-specific operational standards that integrate engineering metrics with local topographic and cultural conditions.
2. **De-silo Institutional Budgets:** Institutional frameworks must merge structural engineering and social mobilisation lines into unified project budgets, protecting community training components from arbitrary cuts.
3. **Institutionalise Intersectional Monitoring:** Monitoring and evaluation frameworks must adopt disaggregated indicators to track access across

intersecting lines of gender, ethnicity, and geography simultaneously.

4. **Mitigate Elite Capture:** Implementing agencies and civil society organisations should introduce formal equity provisions, such as gender leadership quotas and separate consultative blocks for marginalised sub-groups, to balance local power dynamics before infrastructure installation.

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REFERENCES

Abdulkadir, H., Usman, A. K., and Abdullahi, A. H. (2023). Open defecation as a challenge to public health in Giwa Local Government Area, Kaduna State, Nigeria. *FUDMA Journal of Sciences (FJS)*, 7(6):342-346.

Abdullahi, A. M. (2023). "Community-led sanitation in northern Nigeria: Between standards and practice", Doctoral dissertation, University of Leeds.

Ajayi, O. O., and Olaleye, K. O. (2023). Groundwater potential and challenges in Bauchi State, Nigeria. *Journal of African Earth Sciences*, 198:104-167.

Ali, A. Y., Beka, N. C., Amba, T. A., Vivan, E. L., Iko, I. I., and Parah, E. Y. (2026). The use of Community-led Total Sanitation (Clts) in the evaluation of sanitation and hygiene situation among the residents of Tafawa- Balewa Town, Bauchi State, Nigeria. *Research Square (Preprint)*, doi:10.21203/rs.3.rs-9003710/v1.

Bain, R., Johnston, R., and Khan, S. (2021). Monitoring drinking water quality in low-income countries: A systematic review. *International Journal of Hygiene and Environmental Health*, 234:113-345.

Carrard, N., Willetts, J., and Neale, E. (2020). Beyond functionality: A review of gender in WASH. *Development in Practice*, 30(2):156-178.

Cleaver, F., and de Koning, J. (2015). Furthering critical institutionalism. *International Journal of the Commons*, 9(1):1-18.

Dauda, M. K. (2021). Traditional power structures and community participation in Bauchi State, Nigeria. *African Studies Quarterly*, 21(3):267-289.

de Albuquerque, C. (2019). The human rights to water and sanitation: An annotated selection of international and regional law and mechanisms. *Water International*, 44(5):78-95.

Ebele, N. E., and Emodi, N. V. (2022). Climate change and water stress in Nigeria's Middle Belt. *Environmental Development*, 41:89-104.

Eze, T., Oruonye, E. D., and Adeoye, P. A. (2022). Decentralization and WASH service delivery in Nigeria: Policy-practice gaps. *Water Policy*, 24(1):112-130.

Ezeaka, N. B., and Bartholomew, C. E. (2025). Navigating environmental sanitation and health communication in Nigeria: Challenges and prospects. *International Journal of Research and Innovation in Social Science (IJRISS)*, 9(1):3381-3389.

Foster, T., Furey, S., Banks, B., and Willetts, J. (2020). Functionality of handpump water supplies: A review of evidence from sub-Saharan Africa. *International Journal of Water Resources Development*, 36(5):678-698.

Grasham, C. F., Korzenevica, M., and Charles, K. J. (2021). Climate resilience in rural water supply. *WIREs Water*, 8(3):412-430.

Harvey, P. A., and Reed, R. A. (2007). Community-managed water supplies in Africa: Sustainable or dispensable? *Community Development Journal*, 42(3):365–378.

John, D., Hassan, U. F., Adamu, H. M., Akanang, H., and Ibrahim, J. S. (2025). Evaluation of some physicochemical parameters in borehole and well water in Tafawa Balewa, Bauchi State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 29(2):367-374.

Kumpel, E., Cock-Esteb, A., Duret, M., de Waal, D., and Khush, R. (2017). Seasonal variation in drinking and domestic water sources and quality in Port Harcourt, Nigeria. *American Journal of Tropical Medicine and Hygiene*, 96(2):437–445.

Kumpel, E., Peletz, R., and Khush, R. (2020). Seasonal water quality in sub-Saharan Africa. *npj Clean Water*, 3(1):345-359.

Mobolaji, J. W., and Akinwumiju, A. S. (2025). Geospatial assessment of household water, sanitation and hygiene conditions and associated factors in Nigeria: A causal relationship model. *PLoS One*, 20(8):e0330167.

Nkiaka, E., Bryant, R. G., Okumah, M., and Gomo, F. F. (2021). Water security in sub-Saharan Africa: Understanding the status of sustainable development goal 6. *WIREs Water*, 8(6):e1552.

Nunes, R., and Fielmua, N. (2023). Institutional bricolage in community-based water management: some insights from non-representational theory. *International Journal of Water Resources Development*, 39(3):404-432.

Ogunbode, T. O. (2025). A nine-year critical review of progress and future strategies for sustainable development goal 6 in Nigeria from 2016 to 2024. *Discover Sustainability*, 6(1):1466.

Olukanni, D. O., and Olajuyigbe, A. E. (2022). Progress and challenges in Nigeria's WASH sector. *Journal of Water, Sanitation and Hygiene for Development*, 12(1):112-125.

Rhodes-Dicker, L., Brown, N. J., and Currell, M. (2022). Unpacking intersecting complexities for WASH in challenging contexts: A review. *Water Research*, 209:117909.

Sommer, M., Zulaika, G., Schmitt, M., et al. (2021). Monitoring menstrual health and hygiene: alignment with the Sustainable Development Goals. *Global Health Action*, 14(1):1920315.

Stoler, J., Guzmán, D. B., and Adams, E. A. (2023). Measuring transformative WASH: A new paradigm for evaluating water, sanitation, and hygiene interventions. *WIREs Water*,

10(5):e1674.

Truelove, Y. (2021). The political ecology of urban water. *Geoforum*, 120:678-692.

Wilbur, J., Ferdous, S., and Wapling, L. (2022). The inclusion of disability and aging in COVID-19 hygiene behavior change interventions across low-and middle-income countries: A review using the COVID-19 Inclusive WASH Checklist. *Frontiers in Public Health*, 10:1024850.