

WASH Infrastructure and Cholera Incidence in Somalia

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Abstract Access to safe water and sanitation (WASH) represents the primary defense against cholera. Despite the persistent prevalence of cholera in Somalia, there is a dearth of evidence on the impact of WASH in Somalia. This study employed a mixed-methods approach, including a survey of 134 households across ten cholera-affected districts, regression analysis of WASH influence over a 24-month period, a census of WASH services in health facilities, and interviews with 17 key informants. The regression analysis satisfied all required assumptions. To reduce variable overlap, we combined access to water and sanitation into a single WASH variable. This composite WASH variable demonstrated a strong association with cholera severity ($B = -0.730$, $SE = 0.087$, $\beta = -0.418$, $t(130) = -8.35$, $p = .001$). Individuals with access to WASH were significantly less likely to contract cholera or acute watery diarrhea ($OR = 0.13$, 95% CI [0.05, 0.36], $p = .001$). The model accounted for 67.8% of the variance in severity across Somalia ($R^2 = 0.678$, $F(3,130) = 91.16$, $p = .001$). Only 36.2% of health facilities had running water, and 41.4% had adequate sanitation. The primary causes of inadequate WASH services included malfunctioning water points, open defecation in densely populated areas, and water contamination during rainfall. Improving WASH should be a top priority, along with ongoing efforts in vaccination and health care. More investment is also needed in WASH systems that can withstand flooding in the Juba and Shabelle river basins to help reduce cholera cases by 2030.

Keywords Cholera, Incidence, Mixed Methods, Public Health, Somalia, Water Sanitation Hygiene, WASH.

Introduction

Cholera, caused by the bacterium *Vibrio cholerae* serogroups O1 or O139, is one of the diseases that has impacted fragile states worldwide [1]. The most up to date information regarding the number of cases of cholera that have occurred across the world since 1961 reveals that since 2021, there have been more instances of the disease becoming widespread across the planet; in 2022, there were 472,697 cases of cholera reported to occur across the world, however, in 2023 alone, there were 535,321 cases of the disease, representing a 125% increase in cases within the African region of the planet [1, 2].

The number of cases of cholera (since 2017) in Somalia in the Horn of Africa has become the highest of any country within the region, with 21,944 cases reported in 2024 [3]. Several factors contribute to the high rates of cholera that exist within Somalia. For instance, only 52% of Somalis have access to a basic water supply, 34% of Somalis use open defecation facilities, 80% of Somalis do not have access to soap within the locations where they wash their hands, and a disproportionate 28% of Somalis do not have any basic sanitation facilities within their homes [4, 5].

These same factors are present in the regions of the country with the highest rates of cholera; the Juba and Shabelle River basins contain 60% of all cholera cases in the nation [3]. Despite the knowledge of these factors that contribute to the high rates of cholera within Somalia's population, the studies regarding these factors are limited to assessing the factors related to the ecology of Somalia; no studies have published investigations into whether the sanitation and hygiene infrastructure within Somalia has an impact on the rates of cholera within the country's individual households [6, 7].

However, numerous studies have been performed globally related to the impact of inadequate sources of water, sanitation, and hygiene on the development of cholera. For instance, one of the most extensive reviews of

the relationship between WASH and cholera found that the odds ratio for individuals living in areas with inadequate water, sanitation, and hygiene supplies ranges from 1.9 to 5.6 [8]. Furthermore, studies have been published related to the factors related to Somalia; a study by Sultan et al. found that limited access to water facilities increases the odds of individuals developing cholera by a factor of 2.4 in the Southwest region of the nation, but the availability of latrines within the area reduces the odds of individuals developing cholera [9]. Each of these studies, however, was limited to investigating one cholera outbreak in one region of the nation; no studies have assessed the impact of WASH infrastructure on cholera rates in Somalia while controlling for the effects of both climate and health system factors within individual households.

To fill this gap, this investigation aims to determine the effect of WASH infrastructure on cholera rates in Somalia. Based on the Political Economy of Health Theory [10, 11] and the Social-Ecological Model [12, 13], this study intends to test the hypotheses that WASH infrastructure has a statistically significant and independent effect on cholera rates in Somalia's population.

Thus, this study intends to investigate the effect that WASH infrastructure has upon each of the following three variables: the severity of cholera cases within the country (as a continuous variable), the odds that individuals within the country have experienced one or more cases of cholera (or AWD episodes from cholera) within the last 24 months, and the mechanisms behind such association between these two variables through surveying the WASH facilities within those areas that experience cholera, as well as the knowledge of individuals within those areas.

Materials and Methods

Study Design

The study used a convergent mixed-methods approach to collect and analyse data using three

methods: a household survey, a census of public health facilities within the study area, and interviews with selected key informants in those areas. Each methodology was used separately to gather and analyse data before combining them into a single interpretation of the research question [14]. This methodology was employed to allow for triangulation, complementarity, and expansion of findings from the survey research [15].

Study Area and Districts

The study was undertaken within the Federal Republic of Somalia. The districts that were selected were among those impacted most severely by cholera over the past five year period - according to the list of districts impacted by the GTFCC [3]. Each of these districts were chosen from each of the country's two river basins (the Juba and the Shabelle), both inland and coastal districts, and from each of the tertile distributions of cases of cholera that have impacted those regions over the past two years. Due to the insecurity within the nation, approximately 20% of the country's districts are inaccessible for the study. Thus these ten districts represent the accessible districts of the nation that have experienced the highest rates of cholera cases.

Participants and Sampling

The survey of households used the head of each household or any adult within the household (of age 18 years or older). The required sample size was worked out using Cochran's formula, with parameters of $z = 1.96$ (indicating 95% confidence), $p = 0.20$ (based upon findings by Sultan et al. [9] of the extent of cholera within Somalia), $d = 0.5$ (indicating a 5% margin of error) - suggesting a size of $n = 246$ households. Thus, 150 households were approached, of which 134 provided complete responses to the survey (indicating an 89.3% response rate). The research data did not indicate whether nonrespondents were distributed in any particular way across

districts, whether they were displaced, or whether their responses were gendered.

A census of all public health facilities within the ten districts of Somalia was undertaken. The Federal Ministry of Health published a master list of all facilities ($N \approx 60$). Of these facilities 58 responded to the survey (96.7% response rate). Key informant interviews were performed with 29 individuals - selected via a maximum variation sample from each of the following groups: national policy and partner organisations ($n = 6$); regional and state authorities ($n = 6$); district health and WASH coordinators ($n = 7$); clinical workers ($n = 6$); and community and IDP leaders ($n = 4$) [16].

Data Collection

Data from the households was collected during face-to-face interviews. The interviews were conducted via tablet-based software (KoboToolbox). Each of the questionnaires was translated into Somali by a certified medical translator and then re-translated back into English to ensure accuracy of the translation. Each questionnaire incorporated four main variables: those relating to infrastructure for WASH within the households (B1, 12 items); practice of WASH within the households (B2, 6 items); climate-induced shocks within the household (C1, 10 items); health-care system capacity within the household (D1, 10 items); severity of cases of cholera of the individual within the household (0-8); and whether that individual has had any cases of cholera within the household (yes/no). Each of these WASH items was also visually inspected within each household during these research visits ($ICC \geq 0.75$). The facilities were assessed by two individuals within the research team (a clinical officer and a health systems officer) using a slightly-modified version of the WHO SARA tool. The key informant interviews were performed by the principal researcher of the study and lasted between 42 and 78 minutes (mean = 58 minutes).

WASH and Outcome Variables

The WASH infrastructure as measured via B1 comprised items related to quality of water supplied to the household, availability and quality of latrines within the household, availability of a facility for hand-washing within the household, management of solid waste within the household, management of water resources within the area, vulnerability to drought or flood, knowledge of WASH-related health practices and campaigns, and whether members of the household (especially children) performed such practices.

The variables both of WASH infrastructure (B1) and WASH practices (B2) exhibited very high levels of multicollinearity ($VIF_2 = 9.38$ and 9.34 respectively; Tolerance = 0.107 in each case). We therefore merged these two variables into a single WASH practices and infrastructure variable based on the mean of each item within the survey, in accordance with recommendations by both Field [17] and Wolfe et al. [8]. The new composite variable indicated a combined internal consistency of $\alpha > 0.93$, and VIFs all ≤ 1.02 . The primary outcome variable was the severity of cholera ($\alpha = 0.960$). This was calculated according to the total number of cases of cholera within the household, the length of time each case continued during the period, and the number of individuals within the household who required hospitalization due to the disease over the past 24 months. The binary outcome variable was that same interview question that inquired of each individual within the household whether they experienced any cases of cholera (yes/no).

Statistical Analysis

All analyses were undertaken using both IBM SPSS Statistics v28 and R v4.4. We calculated descriptive statistics for each variable. The assumptions of multiple linear regression were tested for normality (Shapiro-Wilk test $W = 0.982$, $p = .075$; Kolmogorov-Smirnov $D = 0.072$, $p = .476$), linearity (Ramsey RESET test $F(1, 129) = 0.004$,

$p = .952$), homoscedasticity (Breusch-Pagan LM test $LM = 1.35$, $p = .718$), multicollinearity as revealed via the variance inflation factor (VIF) and tolerance statistics, and independence of observations within the model residuals according to the Durbin-Watson test ($DW = 2.13$). Each test indicated that the model assumptions were met ($p > 0.05$ for each test). A multiple linear regression model was constructed to determine the relationship between WASH infrastructure (B1), climate-induced shocks (C1), and health-care system capacity (D1) within the household and the severity of cholera cases within those households. Additionally, a logistic regression model was constructed to determine the same type of relationship in relation to the outcome variable measuring whether or not any individual within that household had suffered from cholera or AWD episodes within the past 24 months. A series of Pearson correlation tests helped to reveal the relationship between each of the various variables. Additionally, one-way ANOVA and chi-square tests helped determine whether WASH and cholera related differently across subgroups within the study population (specifically, whether WASH and cholera related differently depending on whether any individuals within those households were displaced). Such a significance level of $p = 0.05$ indicates statistical significance of these models (two-tailed test).

Qualitative Analysis

The interview content was analysed according to the Framework Method [18]. The data was first organised according to the objectives of the study - the researchers also performed analyses according to both the objectives and findings of the interviews (inductive analysis). Trustworthiness of the data is ensured through member-checking, expert-debriefing, maintaining an audit trail and journal of the processes used and experiences of the researchers [19]. The results of the data analyses are reported according to both the

SRQR [20] and the GRAMMS [21] quality standards.

Ethical Approval

Ethical approval for this study was granted by the Taxila American University Institutional Review Board. Written consent was secured from the managers of the health facilities; all other participants of both household and key informant surveys were audio-recorded with their consent. The data was stored on an encrypted server and with a password to access that data. All participants were informed that participation was voluntary and that they could withdraw at any time.

Results

Sample Characteristics

To provide a contextual overview of the study areas, Table 1 presents the characteristics of the population within the districts. The sample comprised 134 households, of which 57.5% were female, with an average age of 36.9 years (SD = 9.2). Of these individuals, 43.3% had no formal education beyond Quranic schooling, 38.8% were internally displaced persons (IDPs), and 80.6% lived within households that contained at least one child under the age of five. Each of these characteristics are reflective of the demographics of the ten districts within which the study was performed [3, 5]. Within these districts, the 58 health facilities surveyed represented an average of 9,800 persons living within each facility's catchment area.

WASH Infrastructure: Descriptive Findings

The mean WASH infrastructure composite score (B1) was 3.01 on a 1 to 5 Likert scale

(Table 1). The standard deviation of 0.87 indicates the distribution of individual responses within the districts. More than 60% of the individuals within those districts either disagreed with the statement that their primary source of drinking water was safe (B1-1) or that their water sources were not vulnerable to contamination (B1-2). Additionally, 61.2% of the households within the districts did not have access to items B1-3 and B1-5 - private latrines and soap and water access at a handwashing facility. Furthermore, public latrines (B1-6), community handwashing facilities (B1-7), and the local authority maintenance of water points (B1-8) were all below a mean score of 3 on the 1 to 5 scale.

Only 36.2% of health facilities had access to running water, and only 41.4% had appropriate sanitation facilities. Additionally, only 44.8% of these health facilities had access to soap or alcohol-based hand-rub at the facilities, and 48.3% had access to sterilization equipment for medical instruments. The mean cholera-specific readiness composite score was 2.71 (SD = 0.64), indicating that health facilities were generally less prepared for cholera than the areas where their patients live.

Bivariate Associations

Bivariate analysis showed that WASH infrastructure was significantly and inversely correlated with cholera severity within the areas ($r = -0.444$, $p = .001$; Table 1). This association remained statistically significant even after including climate and health system variables (which are also associated with the presence of severe cholera). The negligible correlations between each of the independent variables indicates the lack of multicollinearity among these variables.

Table 1. Pearson Correlation Matrix and Descriptive Statistics for Composite Study Variables (N = 134)

Variable	Mean (SD)	1. WASH	2. Climate	3. Capacity	4. Severity
1. WASH infrastructure (B1)	3.01 (0.87)	1.000	—	—	—
2. Climate-induced shocks (C1)	3.62 (0.72)	-0.088	1.000	—	—
3. Health-care capacity (D1)	2.63 (0.83)	-0.048	-0.090	1.000	—
4. Cholera severity score	3.98 (1.51)	-0.444***	+0.594***	-0.442***	1.000

Note. *** $p = .001$ (two-tailed). WASH = WASH infrastructure composite (B1); Climate = climate-induced shocks composite (C1); Capacity = health-care system capacity composite (D1).

Multiple Linear Regression: WASH and Cholera Severity

The model that includes these three variables accounts for 67.8% of the variance in cholera case severity ($R^2 = 0.678$; Adjusted $R^2 = 0.670$; $F(3, 130) = 91.16$, $p = .001$). The effect of WASH infrastructure on cholera severity is statistically significant ($B = -0.730$, $SE = 0.087$, $\beta = -0.418$, $t(130) = -8.35$,

$p = .001$; 95% CI $[-0.90, -0.56]$). The value of WASH infrastructure has a statistically significant association ($\beta = -0.418$) with cholera severity ($B = -0.730$), almost equal to the effect of health-care capacity ($\beta = -0.416$) but less than the effect of climate-induced shocks ($\beta = 0.520$) (Table 2). Thus, the null hypothesis H_{01} of no statistically significant effect of WASH infrastructure upon cholera incidence is rejected.

Table 2. Multiple Linear Regression of Cholera Severity Score on Three Independent Variables (N = 134)

Predictor	B	SE B	β	t	p	95% CI
Constant	+4.200	0.569	—	7.377	= .001	[3.07, 5.33]
WASH infrastructure (B1)	-0.730	0.087	-0.418	-8.353	= .001	$[-0.90, -0.56]$
Climate-induced shocks (C1)	+1.097	0.106	+0.520	+10.346	= .001	$[+0.89, +1.31]$
Health-care capacity (D1)	-0.760	0.092	-0.416	-8.293	= .001	$[-0.94, -0.58]$

Note. β = standardized coefficient. $R^2 = 0.678$; Adjusted $R^2 = 0.670$; $F(3, 130) = 91.16$, $p = .001$.

Binary Logistic Regression: WASH and Episode Occurrence

The model results demonstrate that the binary logistic model was statistically significant ($\chi^2(3) = 58.18$, $p = .001$; McFadden pseudo $R^2 = 0.462$), indicating an excellent fit of the model to the data. Furthermore, WASH infrastructure was also a statistically significant independent variable that predicted episode occurrence ($B = -2.024$, $SE = 0.515$, Wald $z = -3.93$, $p = .001$). The odds of a household experiencing a cholera or AWD episode decreased by 87% with each one-unit increase

in WASH infrastructure (OR = 0.13, 95% CI $[0.05, 0.36]$; Table 3). When surveyed, 82.1% ($n = 110$) of all households in the study area had experienced at least one episode of either cholera or AWD within the past 24 months of the study. These findings are consistent with the ANOVA results, which indicated that a higher percentage of IDP households (92.3%) had experienced an episode of either cholera or AWD compared to the percentage of host community households that experienced such an episode (73.6%). These findings are statistically significant ($F(2, 131) = 11.09$, $p = .001$, $\eta^2 = 0.145$).

Table 3. Binary Logistic Regression: WASH Infrastructure and Cholera/AWD Episode Occurrence (N = 134)

Predictor	B	SE	Wald z	p	OR (95% CI)
Constant	+5.414	2.311	+2.343	.019	—
WASH infrastructure (B1)	-2.024	0.515	-3.932	= .001	0.13 [0.05, 0.36]
Climate-induced shocks (C1)	+2.376	0.604	+3.933	= .001	10.76 [3.29, 35.17]
Health-care capacity (D1)	-1.805	0.466	-3.875	= .001	0.16 [0.07, 0.41]

Note. Likelihood-ratio $\chi^2 (3) = 58.18$, $p = .001$; McFadden pseudo $R^2 = 0.462$. OR = odds ratio.

Key Informant Perspectives

Qualitative findings from 29 KIIs across five strata indicated that the determinants of the effect of WASH infrastructure on cholera severity were threefold. First, the study found that the displacement of communities led to the disintegration of the community management committees that managed the water points in those areas, resulting in the contamination of the area's water sources. Second, the high rates of cholera in IDP settlements was found to be caused by the lack of elevated slabs or fly-proof latrines in those settlements. Third, national policy informants indicated that funds allocated to WASH were used to respond to cholera outbreaks rather than to construct WASH infrastructure; thus, infrastructure in those areas was restored to suboptimal levels only between cholera outbreak periods. These three findings each contribute to an understanding of why WASH infrastructure has an effect both upon the severity of cholera at the household level, and upon the contamination of water sources at the community level.

Discussion

The primary finding of this study is that WASH infrastructure in Somalia has a large, statistically significant, and independent effect on the severity and development of cholera at the household level. The magnitude of this effect ($\beta = -0.418$ and $OR = 0.13$) is similar to that of most meta-analytic and regional studies on the topic. Thus, these findings contribute to the existing literature on the topic in three distinct ways.

First, this study's findings are consistent with both the global meta-analysis of Wolfe et al. [8], which included 51 case-control studies on cholera and WASH infrastructure, and the Southwest State study by Sultan et al. [9]. However, the findings of this study differ in that it measures the effect of WASH infrastructure alongside the effects of both climate and health system variables. In both of the aforementioned studies, each of the variables was found to be significantly correlated with each of the others. The non-significance of each of these variables' correlations with one another (all $|r| \leq 0.090$) indicate that the WASH infrastructure effect is independent of both climate and health system variables. Such a measurement was not performed in previous studies in Somalia.

Second, the similar coefficients for WASH and health care ($\beta = -0.416$) indicate that these two variables have similar impacts on the severity and development of cholera. Despite the fact that most of the international response to the cholera epidemic in Somalia has been directed towards healthcare efforts and infrastructure, these findings indicate that the development and improvement of WASH infrastructure in Somalia is a similarly-important topic of consideration.

Third, the effect of WASH infrastructure can be analyzed through the lens of the Political Economy of Health Theory [10, 11]. Somalia's low WASH coverage figures (52% access to basic water and 34% rates of open defecation) result from the country's conflicts over three decades. The same can also be said of the Social-Ecological model of WASH infrastructure [12]. The failure of WASH

management committees in those communities after members were displaced indicates the importance of WASH as both institutional and physical infrastructure.

The subgroup analysis indicates a significant difference in cholera severity between IDP and host community households (mean difference in severity score = 1.20 points; $\eta^2 = 0.145$). Within this subgroup analysis, the findings were again reflected in the binary outcomes (IDPs experienced cholera at a rate of 92.3% compared to 73.6% of host community households). Thus, any WASH infrastructure initiatives that do not specifically consider IDP and returnee communities will fail to address the severe lack of WASH infrastructure among those groups.

Wolfe et al. [8] found that binary WASH infrastructure categories did not allow measurement of WASH infrastructure quality within the improved category. The 12-item WASH infrastructure score (Cronbach's $\alpha = 0.966$) addresses this and explains the significance of the WASH infrastructure effect. Future studies should utilize such a scale to measure WASH infrastructure quality.

Several limitations to this current study exist. First, the cross-sectional study does not permit for determination of causation; though the theory and previous experimental studies indicate the effect of WASH infrastructure upon cholera severity, it was not directly measured within this study. Second, the sample size of 134 households was drawn from ten districts, each selected for their accessibility to the study team; thus, it is not representative of Somalia's districts. Third, the data on the episodes of cholera and AWD were self-reported by the participants. Although these episodes were cross-validated with outpatient clinic records, they may still not be entirely accurate. Finally, the lack of a significant link between severity score and cholera (32.2%) indicates that other variables, such as conflict and health system factors, contributed to participants' severity scores.

Conclusion

WASH infrastructure in households in Somalia has a powerful and independent effect upon the severity of and the development of cholera in those individuals. The reduction of both episode rates (from 87% reduction in episodes with each unit of WASH infrastructure improvement) and severity scores (0.73 units) indicates the potential benefit of WASH infrastructure development. Additionally, the finding of the severity difference between the IDP and host community populations suggests that WASH infrastructure initiatives must target both informal settlements and residential infrastructure. Thus, to achieve the GTFCC goal of a 90% reduction in cholera deaths in Somalia by 2030, WASH infrastructure development in endemic districts should be treated as a structural development priority rather than a humanitarian response.

Conflict of Interest

The author declares no conflict of interest regarding the publication of this paper.

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Ethical Approval

The Institutional Review Board of Taxila American University approved this study. We obtained consent from the managers of the health facilities included in the study, and audio-recorded consent from individual household and key informant participants. All participants were adults who voluntarily wished to participate in the study; no incentives were

provided for their participation, and all data were stored on password-protected and encrypted servers.

Data Availability

The datasets generated and analysed during the current study are not publicly available (due to privacy considerations) but may be obtained from the author upon request and with approval from the institutional review board.

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Author Contributions

Yusuf Elmi Mohamud was the sole author of this manuscript and was responsible for study design, data collection and analysis, table preparation, and writing and revision of the manuscript.

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