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Original Article

Factors associated with the cholera outbreak in Al-Mahweet-Yemen: Analytic Study

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Abstract

Introduction: The emergence of cholera in 2016 in Yemen, worsened the morbidity and mortality of diarrheal diseases, particularly among children under five. Multiple outbreaks in Yemen are triggered by years of conflict and the collapse of basic infrastructure including water supply and sanitation systems. This study aims to assess factors associated with the cholera outbreak, in a cholera-prone region, in Al-Mahweet, Yemen.

Methodology: We conducted a multivariate analysis of the data collected through a household survey of 384 households in Al-Mahweet, Yemen.

Results: Families with children under five years, large households, and those living in Al Mahweet district were associated with a higher incidence of cholera. Water treatment by boiling, filtering, and chlorination as a protective practice against cholera showed a borderline significance, while other WASH practices including regular hand washing, open defection, safe water source, and improved sanitation facilities were statistically insignificant. Community awareness of cholera transmission and prevention measures showed no association with cholera incidence.

Conclusions: Findings suggest that living conditions, including large households and lack of access to treated water, increase the risk of cholera. Interventions to increase access to treated water and improve the hygienic conditions of large households are of central importance. Affected communities must receive effective educational campaigns that are adjusted to change hygienic practices and improve knowledge of cholera transmission and protection measures.

Key words: Cholera; knowledge; WASH; Yemen.

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Introduction

Cholera is an acute intestinal infection due to exposure to a bacterium called *Vibrio cholera* for which the only known natural reservoir is humans [1,2]. The transmission is closely related to limited access to safe drinking water and proper sanitary systems. Areas with inappropriate water treatment, inadequate sanitation, and improper hygiene practices are considered ideal places for cholera prevalence [1,3]. Cholera is a preventable and treatable illness, in which up to 80% of cases can be efficiently cured by oral rehydration solution (ORS). The provision of clean water and safe sanitation are crucial preventive measures to control an outbreak of cholera and other waterborne infections [1,3]. Historically, six subsequent pandemics killed millions of people all over the globe. The first cholera pandemic appeared in 1817 in Southeast Asia, and the current (seventh) pandemic began in Indonesia in 1961 and reached Africa a decade later and the Americas in 1991 [4].

Cholera represents a huge public health problem. Estimates indicate 2.9 million cases and 95,000 deaths annually in 69 endemic countries. A billion and three hundred thousand people living in 69 endemic countries are at risk for cholera, and around 7.50 deaths per 100,000 population are at risk for death from cholera annually in these countries [5].

Yemen is situated in the Arabian Peninsula in southwestern Asia. It has around 31.5 million population as of 2019 [6]. There was a long history of political instability in the last 60 years, and together with the current conflict that started in 2015, it has become one of the poorest countries in the world [7]. Yemen has been affected by the worst cholera pandemic in the modern era, with more than 2.5 million cases and 3,845 deaths as of January 2021 [8,9]. The

epidemic is represented by three main waves, the first was in mid-December 2016 with 1935 cases per week, the second and most aggressive wave was in late June 2017 with 50832 cases per week, and the third wave in June 2018 with a total of 26308 suspected cases per month. Of these 29% are children below 5 years, and the case fatality rate (CFR) is 0.17% [8,10].

A variety of factors facilitate cholera outbreaks including water, sanitation, and hygiene (WASH) conditions, malnutrition, conflict, and weather-related factors. Unfavorable WASH factors are essential determinants for diarrheal diseases including cholera [1,11,12]. Several factors drive the outbreak in Yemen. Dureab *et al.* found that behavioral factors, use of common-source water, failure to wash fruits and vegetables, consumption of Khat, and nonuse of chlorine and other hygienic solutions in household activities, are potential risk factors for cholera [13]. Likewise, a community-based comparative survey conducted in 2017 in Aden, Yemen suggested that socioeconomic, water, sanitation and hygiene conditions are important factors associated with cholera [14].

Conflict and its associated context are also implicated in the occurrence of cholera. The recent cholera outbreak in Yemen can be an example of the implication of the conflict. Dureab *et al.* suggested a clear relationship between conflict and the occurrence of cholera and demonstrated a positive relationship between population displacement and the number of cholera cases [15]. Another study also indicated a positive correlation between the severity of the conflict and the number of cholera cases and indicated a relationship between cholera cases and both the number of internally displaced people (IDPs) and the number of returnees [16]. According to a recent case study on the cholera situation in three main governorates of Yemen, it was found that several, rather than single, driving factors were involved in the outbreak, all of which were a result of the armed conflict. Armed conflict is accused as the major driver of the disrupted infrastructure, particularly water supply and sanitation systems [2].

Evidence suggests that awareness campaigns and information dissemination have a significant role in minimizing the spread of infections [17,18]. A review of the literature revealed a positive impact of awareness interventions to control cholera [11]. A community-based survey conducted in Dhaka, Bangladesh, revealed that almost half of the household members that were assessed had poor knowledge of cholera prevention and transmission. The study results demonstrated a poor level of knowledge on cholera among high-risk groups and suggested that strengthening health awareness programs may, therefore, upgrade their knowledge of cholera [19]. Another study suggested that the public health messages were successful to encourage behavioral changes related to cholera prevention [20]. There was poor knowledge of cholera transmission among the population in Yemen. Al-Sakkaf *et al.* [14] found suboptimal knowledge of cholera transmission and prevention among both high and low epidemic areas in Aden, Yemen.

The current ongoing conflict in Yemen has caused huge destruction to the country's infrastructure, including water supply, sanitation, and health care systems, leaving 20.7 million people (66 percent of the population) in need of some form of humanitarian or protection assistance. Of those 15.4 million people lack access to adequate clean water, sanitation, and hygiene, with 8.7 million in acute need [21]. The collapse of the infrastructure together with the economic crisis, high prevalence of severe food insecurity, malnutrition, and lack of community knowledge on basic hygiene and sanitation practices have depressed the overall response to cholera [2,21,22], aggravated more by the COVID-19 pandemic and diversion of the resources [23]. While our understanding of the community's cholera prevention and WASH practices is still limited, effective and timely interventions to control future outbreaks form a public health challenge. Therefore, it is crucial to analyze the association between the community knowledge of cholera prevention measures, WASH practices, and the incidence of cholera. To provide practice-based evidence for health authorities and policymakers that helps them to design cost-effective behavioral change and cholera prevention interventions.

Methodology

Study Design

This is an analytical cross-sectional study, presenting a "snapshot" of certain characteristics of a situation in a community at a particular time, and analyzing its association with the occurrence of cholera.

Description of Study Area and Target Population

Al-Mahweet is a mountainous governorate located in northwestern Yemen with a population of about 718,683 residents, who are distributed in 9 districts, 115 Sub-districts, and 1264 villages. Reports have shown that Al-Mahweet governorate was one of the top 5 governorates affected by the outbreak [9].

Study Population

The study population for the survey included households (HHs) located in the first level of the catchment area for 16 health facilities (HFs) that were supported by the German Corporation for International Cooperation, (GIZ)-Yemen in Al-Mahweet governorate.

Sampling and Sample Size

The sample size was calculated to be 384 households using the following parameters: population size 282,664, 5% confidence limits, 95% confidence level, and percentage frequency of outcome factor in the population was considered at 50%. However, the final sample size after data processing was 352. A total of 352 household caregivers were enrolled through multistage-cluster sampling.

Data Collection, Validity and Reliability

Data from the primary survey were collected through face-to-face interviews, using a structured pretested questionnaire. The assessment was based on the WHO and United Nations Children's Fund (UNICEF) Joint Monitoring Programme for Water Supply and Sanitation (JMP) core questions on drinking water and sanitation for household surveys [24]. Data on demographic and socio-economic characteristics and knowledge, attitudes, and practices regarding safe water, sanitation, and hygiene, diarrheal disease, and cholera. Observations were made by interview teams for household characteristics, water storage containers, and the presence of latrines, handwashing stations, and soap. Quality control measures were followed by the primary survey team to ensure valid data. All data collection was monitored and reviewed daily by the field team supervisor and double-checked by the survey coordinator. The whole process was supervised by Ministry of Public Health & Population team (MoPHP) and GIZ-Yemen. Data for cholera as dependent variable were self-reported according to suspected cholera case definition: "Any patient presenting 3 or more liquid stools with or without vomiting for the last 24 hours should be considered as suspected cholera case" (standard case definition used during the epidemic settings in Yemen) [25].

Data Analysis

Data were imported from an Excel spreadsheet and then analyzed using STATA 16.0 version. After data cleaning and harmonization, descriptive analysis was initially performed and then bivariable and multivariable analyses were conducted. A scoring system was used to measure the level of knowledge about diarrhea cholera prevention measures. A score of 'one' was assigned for correct responses and a score of '0' for incorrect responses. Nine items were used in the knowledge score calculation, with a minimum overall score of 0 and a maximum of 9. A knowledge score of ≤ 5 (equal to or less than five) was considered poor knowledge, while a score of ≥ 6 (equal to or greater than six) was considered good knowledge [19]. Water sources were classified as improved and unimproved according to JMP guidelines, so, questions on water sources 1-5, 7, 10, 11, 12 in the questionnaire were considered improved, and 6, 8,9,13, and 14 are considered unimproved (WHO, 2017b). Regarding water treatment, those with daily practice of treating water were considered Yes (code 1), and those with no treatment were treated as No (code 0). Relevant statistical tests were done, and both crude and adjusted odds ratios (aOR) were calculated, 95 % confidence interval (CI) and the P-value were determined. The significance level for the outcome of statistical tests was considered at 5% ($p < 0.05$).

Ethical approval

This study used secondary data analysis of a primary survey conducted in Yemen in 2018, and an

Table 1. Sociodemographic characteristics of the study population (n = 352).

Characteristic	Total (n = 352), N (%)
Age (years)	16;26;34;41.5;78 *
Age	
16-30	155 (44.03)
31-40	108 (30.68)
41-78	89 (25.28)
Sex	
Male	20 (6.20)
Female	332 (94.32)
Household size	
< 5	55 (15.63)
5-10	221 (62.78)
> 10	76 (21.59)
Children under 5 years	**216 (61.36)**
Educational level	
Illiterate	180 (51.14)
Primary education	76 (21.59)
Secondary education	61 (17.33)
Read and write	35 (9.94)
Household conditions	
Electricity	327 (93.90)
Refrigerator	99 (28.13)
Television	225 (63.92)
Radio	81 (23)
Mobile phone	323 (91.76)
Al-Mahweet city area	22 (6.25)
Cholera	144 (40.91)

* minimum; 1st quartile; median; 3rd quartile; maximum.

explicit ethical statement was not necessary. However, it is in line with the Declaration of Helsinki (2008) which focuses on obtaining ethical clearance, informed consent, and ensuring the privacy and confidentiality of research participants, as well as covering the risks and benefits of research for participants.

Results

Sociodemographic and Household Characteristics (352 HHs)

The socio-demographic characteristics of the study population are shown in Table 1. The age of the respondents ranged from 16 to 78 years with a mean age of 35 years. There was female sex predominance among participants (94%). The average household (HH) size was 8 (Standard deviation SD = 4.3). Forty percent of households reported a history of suspected cholera in the past 7 days before the interview 144 (41%).

Distribution of WASH Characteristics and Practices

The study found the main sources of drinking water among HHs were communal standpipe (38.1%), water truck/ water vendors (21%) and others (40.9%), as shown in Table 2. While the main sources of water for cooking and handwashing were communal standpipes (31.8%), water trucks (12.5%) and other sources (55.6%) as shown in Table 2.

Sixty percent of the respondents reported improved water sources and only 37.5% of the respondents reported water treatment practices. Most of the households (62.5%) did not treat water, to ensure its safety, and 77.7% of them believed their water source was safe.

Different methods of water treatment were reported by 37.5% of respondents including water boiling (37.1%), straining through cloths (34.8%), using a water filter (29.5%), and adding bleach/chlorine solution (23.9%).

Most of the respondents reported regular hand washing (75%), two-thirds washing their hands after using the toilet (75.3%), before eating (91.5%), after cleaning baby diapers (19.9%), and after cleaning the home (59.4%). The majority reported a basic hygiene facility (78.9%). However, evidence of open defecation was observed in 25% of HHs.

Knowledge about Diarrhea/Cholera Prevention

Study population knowledge related to diarrhea or cholera prevention measures is presented in Table 3. All households had nearly suboptimal knowledge, however, only 11% of the households had an overall good knowledge score.

Associations between Cholera and Sociodemographic, Knowledge and WASH Characteristics

Table 4 shows the distribution of associations between HH characteristics, community knowledge, WASH practices, and cholera.

Sociodemographic Characteristics

On bivariable analysis, there was a statistically significant positive association between cholera and both HHs with children under five years (OR, 1.7; 95% CI, 1.1-2.68; $p = 0.01$) and HHs residing in Al-Mahweet city (OR, 3.3; 95% CI, 1.3-8.5; $p = 0.007$).

Table 2. WASH characteristics of the study population.

Characteristic	Total (n = 352) n (%)
Drinking water sources	
Communal standpipe	134 (38.07)
Water truck/vendor	74 (21.02)
Others (wells, rainwater, springs, and bottled water)	144 (40.91)
Water sources for other domestic uses	
Communal standpipe	112 (31.82)
Water truck/vendor	44 (12.5)
Others (wells, rainwater, springs, and bottled water)	196 (55.68)
Having improved water sources	212 (60.23)
Treating water	132 (37.50)
Water filter (n = 132)	39 (29.55)
Water boiling (n = 132)	49 (37.12)
Strain using cloth (n = 132)	46 (34.85)
Add PUR sachet (n = 132)	14 (10.6)
Water chlorination (n = 132)	31 (23.48)
Recent daily water treatment practice (n = 132)	110 (83.3)
Regular hand wash	265 (75.28)
Hand wash after using a toilet	265 (75.3)
Hand wash before eating	322 (91.5)
Hand wash after cleaning baby diapers	70 (19.89)
Hand wash after cleaning home	209 (59.38)
Basic hygiene facility (n = 347)	274 (78.96)
Improved sanitation facility	182 (51.7)
Having a closed toilet on observation (ISF) (n = 344)	20 (5.8)
Open defecation (n = 317)	80 (25.24)

Table 3. Knowledge of preventive practices.

Knowledge characteristic	Total (n = 352) n (%)
Good knowledge about cholera prevention	39 (11.08)
Adequate food safety *	80 (22.73)
Regular hand wash	307 (87.22)
Proper waste disposal	207 (58.8)
Use of safe water; treat with chlorine	311 (88.35)
Cholera vaccine	351 (99.72)

*: washing fruits and vegetables thoroughly, cooking food adequately, covering food and saving it away from flies, clean cooking utensils.

Similarly, there was a statistically significant association between cholera and HH size with a significant linear trend (P test for trend = 0.001); HHs with a size of more than 10 members have a 6.76 higher odd of incidence of cholera than HHs with a size of fewer than 5 members (OR, 6.76; 95% CI 1.6-28.3; p = 0.009).

Knowledge and WASH Characteristics

There was no association between good knowledge of cholera preventive measures and cholera occurrence (OR, 0.9; 95% CI, 0.45-1.76; p = 0.74). In the multivariable analysis, only household water treatment practice (HWT) remained a significant protective factor, whereas other WASH characteristics, including regular hand washing, open defection, safe water source, and improved sanitation facilities lacked evidence of an association with the emergence of cholera.

While the association between improved water sources and the occurrence of cholera was statistically insignificant, (OR, 0.8; 95% CI, 0.54-1.28; p = 0.40), daily household water treatment (HWT) showed a borderline significant association (OR, 0.35; 95% CI, 0.12-1.1, p = 0.06).

Hygiene and sanitation factors showed a non-statistically significant association with the occurrence of cholera. Sanitary and hygienic measures, including the availability of closed toilets on observation, access to an improved sanitation facility (ISF), or a basic hygiene facility (BHF), and regular hand washing were not significantly associated with a decrease in cholera incidence (OR, 0.7; 95%CI, 0.28-1.92; p = 0.52), (OR, 0.87; 95% CI, 0.52-1.47; p = 0.60), (OR, 0.8; 95% CI, 0.49-1.32; p = 0.39) respectively. However, open defecation was not significantly associated with the emergence of cholera (OR, 1.34; 95% CI, 0.8-2.2; p = 0.24).

Multivariate analysis has been only performed for variables that showed enough or borderline evidence of association with cholera in bivariable analysis, and the results showed that large family size remained risk factor for cholera, while daily water treatment was a protective factor.

Discussion

This study has been designed to assess factors associated with the cholera outbreak, in a cholera-prone region, in Al-Mahweet, Yemen. The study indicates that there is an association between cholera occurrence and large family size, especially those with more than 10 members. Potential explanations are 1) This is related to the Yemeni family structure, where the majority of the HHs consist of several families living together in the same house and using a shared toilet. These findings are consistent with the other studies in other contexts, one of which is a study reported by Baker *et al.* that showed that shared toilets are proposed

Table 4. Bivariable and multivariable analysis of associations between sociodemographic, knowledge and WASH characteristics and cholera.

Characteristic	Crude OR (95% CI, p*)	Adjusted OR (95% CI, p**)
Age of respondent		
16-30 (reference)	-	-
31-40	0.7 (0.4-1.2, p = 0.20)	-
41-78	0.9 (0.5-1.5, p = 0.72)	-
Sex		
Male	-	-
Female	0.8 (0.33-2.1, p = 0.70)	-
HH/Family size		
< 5 (reference)	-	-
5-10	2.3 (1.16-4.57, p = 0.01) ++	3 (0.9-9.7, 0 = 0.06) ++
> 10	3.4 (1.5-7.6, p = 0.001) ++	6.76 (1.6-28.3, p = 0.009) ++
Children under five	**1.7 (1.1-2.68, p = 0.01) ++**	**1.5 (0.3-1.2, p = 0.15)**
Area (Al-Mahweet city vs others)	3.3 (1.3-8.5, p = 0.007) ++	3.4 (1.3-9.8, p = 0.01) ++
Mobile phone	1.9 (0.8-4.4, p = 0.12)	-
Good knowledge of cholera prevention	0.9 (0.45-1.76, p = 0.74)	-
Improved drinking water sources	0.8 (0.54-1.28, p = 0.40)	-
HH daily treatment of water before drinking		
Yes	0.33 (0.12-0.91, p = 0.02) ++	0.35 (0.12-1.1, p = 0.06) +
No	3 (1.1-8.1, p = 0.02) ++	
Having closed toilet on observation (ISF)	0.7 (0.28-1.92, p = 0.52)	-
Open defecation (OD)	1.34 (0.8-2.2, p = 0.24)	-
Regular hand wash	0.8 (0.49-1.32, p = 0.39)	-
Basic hygiene facility	0.87 (0.5-1.5, p = 0.60)	-

OR odd ratio; CI, confidence interval; * chi square test; ** Wald test; ++ statistically significant; + borderline/weak evidence.

risk factors for diarrhea [26]. Another study in Manila revealed positive correlations between cholera incidence rates and the number of persons per sanitary facility [27]. 2) Yemeni families also eat and live closely together with a high possibility of transmission of infectious diseases, this was suggested by early studies that identify overcrowding as a risk factor for cholera [27]. In this instance, the presence of more members in a family can increase the rate of interpersonal transmission and the potentiality of close contact. Furthermore, large families may represent a huge socioeconomic burden on the family which affects family health, education, nutrition, and susceptibility to infections. Findings of this study confirmed the empirical hypothesis that large families represent a huge socioeconomic burden on the family which affects family health, education, nutrition, and susceptibility to diseases.

The results of this study are also in line with those of previous studies, Endo and his colleagues suggested that HHs size and composition are one of the main ways of transmission because their members are daily in close contact with each other for example at a conversational distance [28]. Similar conclusions indicated the role of family and households in infection transmission in several studies [29-31]. Our findings suggested that HHs with children under five were more likely to be at risk of cholera infection. This is congruent with findings from other studies which concluded that family composition significantly influences the risk of infection and suggested that children are the largest source of secondary spread of infection [28]. Another study reported that children are more susceptible to health impacts [31].

Our results suggested a possible correlation between the area of residence and the occurrence of cholera, in this, Al-Mahweet district reported a higher number of cholera infections compared to the other districts in Al-Mahweet. We expected that because Al-Mahweet city is the center of the governorate with more health facilities per 100,000 inhabitants and better access to health facilities, less transmission of cholera would be observed. One possible explanation is that Al-Mahweet city has a higher population density of Al-Mahweet, so the probability of cholera transmission is higher, which goes along with the findings reported from a study in Manila linking population density with a higher incidence of cholera infection [27]. Another possible explanation is that although the city of Al-Mahweet was expected to be more developed compared to the surrounding districts, the water supply and sanitation infrastructure were very poor. A recent WASH Secondary Desk Review assessment by the Yemen WASH cluster found that the Al-Mahweet governorate has the lowest rate of improved access to water, and is in pressing need of means of water supply [32].

Results from this study showed no association between the householders' knowledge and cholera. Similar conclusions were found in other studies, explaining that knowledge is not essentially always translated into real practices [33-35]. This finding may seem context-dependent, as researchers from Kenya found during the 2015 cholera outbreak, that a lack of knowledge about cholera was a defining risk factor for cholera [36]. Furthermore, cholera educational interventions, awareness campaigns, and information dissemination to improve community knowledge were essential to prevent outbreaks, like cholera [11,17-20]. The small sample size of this study could not refute the association between community knowledge and the incidence of cholera. However, the low level of knowledge observed among this population emphasizes the importance of the expansion of community awareness campaigns which should go along with the cholera response plan.

WASH characteristics are essential determinants for cholera morbidity and mortality [1,3,4,37]. The present study demonstrates that HHs who treat water daily, using different methods such as filtration, solar disinfection, and chlorination are less likely to contract cholera. These findings are likewise reported in other studies where water treatment and provision of safe drinking water were identified as essential measures to protect communities from water-borne diseases such as cholera [1,11,37-41]. A non-randomized controlled trial conducted in a cholera-endemic region in Bangladesh showed that simple water filtration using sari or nylon significantly reduces cholera incidence [42]. Another study in cholera-prone regions in India showed that water chlorination reduces the risk of cholera transmission [43].

The results of this study did not show a significant difference in the occurrence of cholera and the existing evidence of open defecation among the population. However, it should be interpreted with caution and the interpretation must be guided by epidemiological knowledge and public health perspective. Although the association at the level of population cannot be concluded based on this study due to a lack of enough evidence for a significant association between cholera and open defecation, there was a positive relationship between open defecation and the occurrence of cholera in the study participants which should not be

overlooked due to the statistical non-significant estimates alone. A significant association has been found in several studies in the literature [36,37,44]. In this study, we found that open defecation close to home is practiced by 25% of households, which means that open defecation is not a common habit for the majority of the population in Al-Mahweet. Therefore, it was not feasible to refute the possible association between the practice of open defecation and the emergence of cholera. Given the small sample size of this study, a statistically significant correlation should be sought by conducting further studies with a larger sample size. Results from this study did not confirm a correlation between cholera and different WASH characteristics and practices, except for what was reported about treating household water and a lower incidence of cholera. Therefore, more studies with a larger sample size to investigate these associations in similar contexts are strongly suggested.

Limitations of this study include that the sample wasn't representative of the entire country as data was collected from one governorate, Al-Mahweet. Findings are better to be interrupted in similar rural contexts. The respondents' knowledge cannot be attributed to the awareness campaigns as the population's baseline data were not available. Due to the small sample some correlations, including the relationship between the community knowledge about cholera's protective measures, WASH characteristics, and incidence of cholera, were inconclusive. Another concern is response bias which cannot be ruled out, as some respondents claim better practices, therefore studies with larger sample sizes and a longer observation period like in cohort studies, or a control comparison such as case control, will facilitate a close observation of people's hygienic practices and enable a better opportunity to test causality.

Conclusions

This study indicates that open defecation, large households, and the use of untreated water contribute significantly to cholera occurrence. These findings support the need to improve WASH practices, particularly water treatment. It can be concluded that not all information is translated into practices, and this may need interventions to improve the outcome of any awareness activities. More effective educational campaigns that successfully target perceived beliefs of susceptibility to infection and health practices of communities in high endemic regions should be considered in any upcoming awareness programs.

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