



Investigation of a 2021 Diarrheal Outbreak in a Coastal Sub-district of Bangladesh and Its Seasonal Pattern

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Abstract

Objectives: Diarrhea is a major health problem in Barisal, a coastal division of southern Bangladesh. In April 2021 a diarrheal outbreak was notified from Barisal health authorities. An investigation team was deployed to describe demographic characteristics and seasonal patterns, identify risk factors of diarrhea in the district, and implement control measures.

Methods: We analyzed seasonality using district health information system for the period 2018–2021 and conducted a matched case-control study in Bakerganj, the most affected sub-district. Cases were residents reporting ≥ 3 loose watery stools within 24 hours during 18 Apr 2021–1 May 2021. Controls were randomly selected from neighbors of a case without any diarrheal illness. Descriptive statistics were used to summarize demographic characteristics and seasonal trends, and multivariable conditional logistic regression was used to assess associations between potential risk factors and diarrheal illness.

Results: A total of 1,027 diarrheal cases were identified during the outbreak in Bakerganj. Cases increased annually in March (pre-monsoon season) and declined from June (monsoon season). We enrolled 66 cases and 132 matched controls. Drinking untreated surface water (adjusted odds ratio [AOR] 11.6, 95% confidence interval [CI] 2.4–56.3), preparing overnight fermented rice (AOR 2.5, 95% CI 1.1–5.3), and performing ablution (AOR 2.4, 95% CI 1.0–5.9) were significant risk factors. Using surface water treated by aluminum potassium sulfate was protective (AOR 0.3, 95% CI 0.1–0.7). Among stool samples, 27% (20/75) tested positive for *Vibrio cholerae* by rapid diagnostic test and 29% (11/38) by culture; 5 of 8 surface water samples tested were positive.

Public Health Recommendations: This outbreak occurred before the monsoon and was linked to untreated surface water for drinking and household activities. Public health authorities should implement preventive measures to ensure safe drinking water and distribute sufficient amounts of aluminum potassium sulfate to treat surface water before the annual surge.

Keywords: diarrhea, outbreak, waterborne disease, *Vibrio cholerae*, case-control study, Bangladesh



Introduction

Diarrhea is the second leading cause of death in children under five years in Bangladesh, having an incidence of 1.4 cases per 1,000 person-years.^{1,2} Around 6.2% of all diarrheal cases are positive for *Vibrio cholerae*.³ Cholera is endemic in Bangladesh and the seasonal periodicity of diarrhea outbreaks depends on existing weather conditions.^{4,5} Most published studies are based on national cholera surveillance data or limited geographic settings and do not adequately capture sub-district level variation or recent temporal trends.⁶ Cholera, a preventable disease, commonly spreads through water contaminated with feces.⁷ In January 2025, Bangladesh introduced the oral cholera vaccination (OCV) campaign in five urban areas. A two-dose regimen was administered to individuals aged greater than one year.⁸

Rainfall, temperature, humidity, and aridity may affect diarrheal disease patterns. Temperate conditions favor the survival and replication of pathogens such as *V. cholerae*.⁹ Bangladesh lies in the tropical monsoon region.¹⁰ Its climate has seasonal variations, from high temperatures to heavy rainfall. The pre-monsoon season occurs from March to May, and the monsoon season occurs from June to October. The pre-monsoon season has the highest average maximum temperatures.¹¹

In Bangladesh, scarcity of drinking water occurs in the coastal areas due to reduced ground water levels during the dry season.¹² Consequently, people living in coastal areas need to use surface waters such as ponds, canals, and rivers, as well as tubewell water for household activities and drinking.¹³ Occasionally, these surface water sources become contaminated and lead to a higher frequency of diarrheal outbreaks.¹⁴ Residents use aluminum potassium sulfate, Halazone tablets, as well as simple boiling to treat surface water before use.¹⁵

Barisal is a coastal division of Bangladesh and is heavily affected by climate change.¹⁶ In the coastal area of Barisal, tube wells serve as the primary water source; however, during the dry season, residents revert to surface water. Data from diarrheal surveillance showed a higher number of diarrhea cases in the dry season.¹⁷ In 2021, the health media monitoring system of the Institute of Epidemiology, Disease Control and Research (IEDCR) detected a marked increase in the average seasonal number of diarrhea cases in Barisal, exceeding established endemic thresholds, which signaled a potential outbreak. Following the notification, the Public Health

Emergency Operations Center of IEDCR deployed an investigation team to the Bakerganj Sub-district, which was identified as the epicenter based on hospital records. The objectives of the investigation were to describe demographic characteristics and seasonal pattern, identify the risk factors that led to the diarrhea outbreak in Barisal and implement control measures.

Methods

Descriptive Epidemiology

The study was conducted in Barisal Division (Figure 1), southern Bangladesh, with a focus on the most affected communities in Bakerganj Sub-district from 18 Apr to 1 May 2021. During this time period, we performed a descriptive analysis by using a line list of cases compiled from inpatient and emergency department registers at Bakerganj Sub-district Hospital. We also analyzed all diarrhea cases recorded in the District Health Information System from 2018 to 2021 for describing seasonal pattern. For both the descriptive and case-control studies, we applied the World Health Organization's case definition for diarrhea, defined as any person reporting three or more loose or watery stools within a 24-hour period.¹⁸ Cholera pathogens were detected by rapid diagnostic test (RDT) and further confirmed by bacteriological culture.

Analytic Epidemiology

A matched case-control study was conducted in Bakerganj Sub-district (Figure 2). Cases were identified through active community-based case finding conducted during the outbreak investigation. For each case, two controls were randomly selected from eligible neighboring households, matched by location and time of exposure. The sample size was calculated for a matched study design based on a conditional logistic regression analysis following standard methods described by Breslow and Day.¹⁹ Assuming 80% power, 5% significance, 22.7% exposure prevalence among controls, and a 1:2 ratio, 66 cases and 132 controls were required to detect an odds ratio of 2.4.²⁰ Data were collected using a pre-tested structured questionnaire covering sociodemographic characteristics, OCV status, clinical features, illness history, water sources, sanitation and hygiene practices, food consumption, and healthcare-seeking behaviors.

Environmental Investigation

We visited the households of the participants and observed their daily household activities and sources of water collection for drinking, hand washing, and for washing utensils. We collected information on water

purification methods, housing conditions, sanitation, and method of household waste disposal. Following the International Centre for Diarrheal Disease Research,

Bangladesh guidelines, we collected water samples from the canal, river, pond and tube well where the residents obtained water.²¹

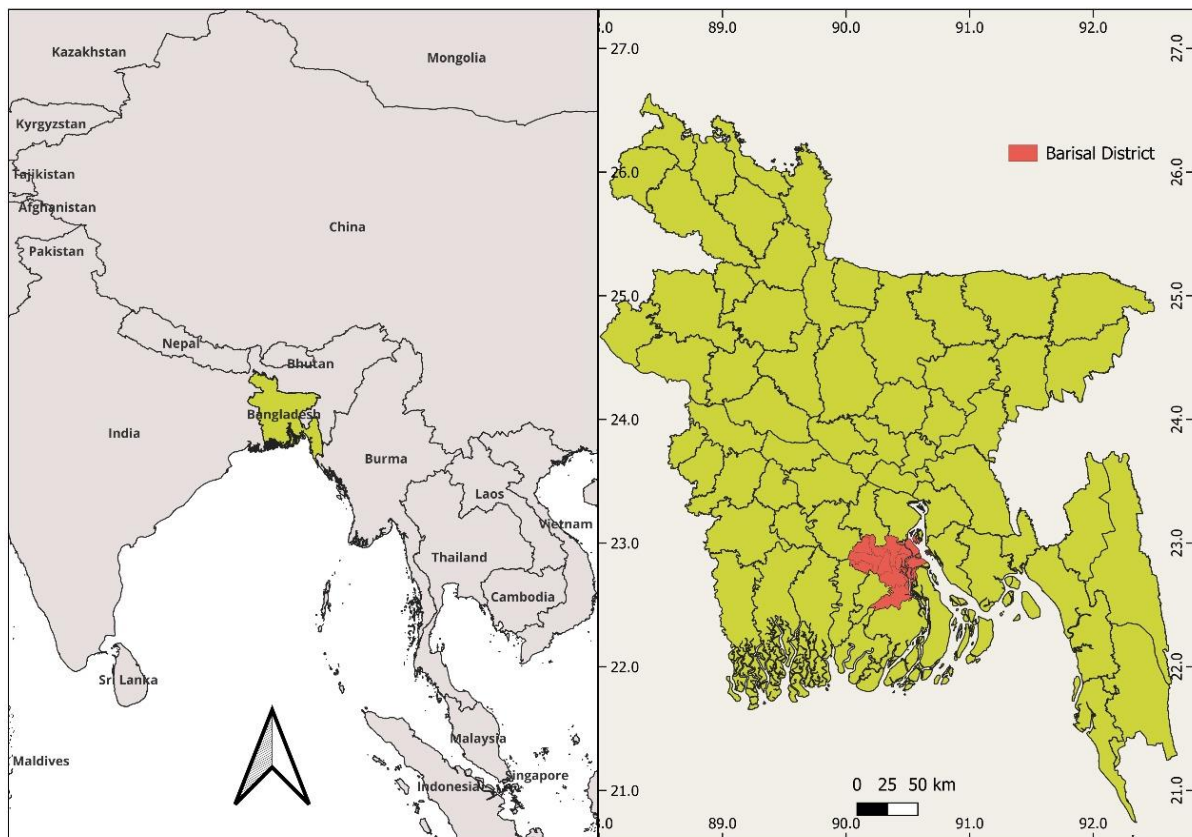


Figure 1. Location of Barisal District, Bangladesh.

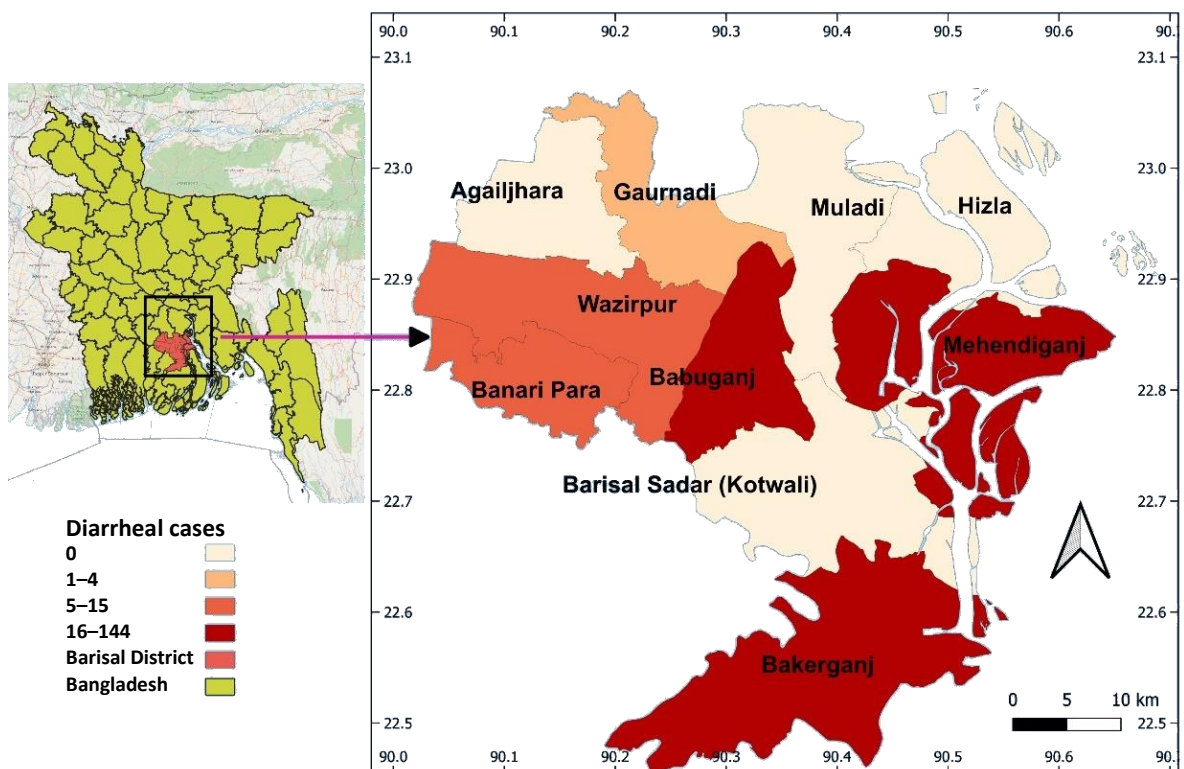


Figure 2. Distribution of admitted diarrhea cases at Barisal General Hospital, Bangladesh, 1–20 Apr 2021 and the location of Bakerganj Sub-district.

Laboratory Investigation

We collected stool samples from cases with no history of antibiotic consumption within the past 24 hours. Samples were tested by a cholera RDT and also sent to the IEDCR laboratory for bacteriological culture of enteric pathogens. Water samples were collected from various surface water sources and tested for enteric pathogens, faecal coliforms, total coliforms, salinity and pH.

Data Analysis and Interpretation

Frequencies with percentages were calculated for demographic characteristics. For matched case-control study, we calculated crude odds ratios and variables having a significant p -value (<0.05) were included in the initial multivariate model. All potential risk factors were initially assessed using univariate analysis, and those found to be statistically significant or considered clinically relevant were included in the

final multivariable conditional logistic regression model. Adjusted odds ratios (AOR) were calculated by a conditional logistic model by using Stata (version 13).

Results

Descriptive Epidemiology

To describe the seasonal pattern of diarrheal disease in the district, we analyzed routine surveillance data from the District Health Information System for the period 2018–2021. Surveillance data showed that diarrhea cases increased each March, remained above endemic levels from April to May, and declined in June, with outbreaks consistently occurring during the pre-monsoon season (Figure 3). The outbreak investigation was initiated following an increase in diarrheal admissions to Barisal General Hospital. Between 1 and 20 Apr 2021, 194 patients were admitted, of whom 144 (74%) were residents of Bakerganj Sub-district, indicating that this area was the outbreak epicenter (Figures 2).

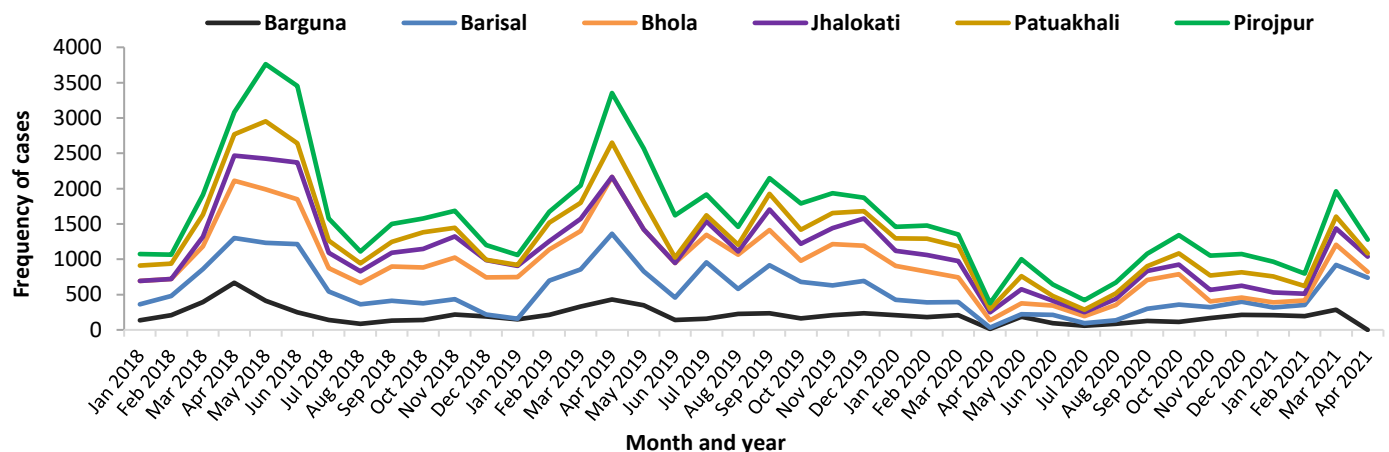


Figure 3. Seasonal trend of diarrheal disease in Barisal Division, Bangladesh, January 2018 to April 2021.

As shown in Figure 4, cases increased rapidly from 11 April, peaking on 18 April, and returned to endemic

levels (around 10 cases/day) by 24 April. Four deaths occurred, one each on 10, 14, 16, and 20 April.

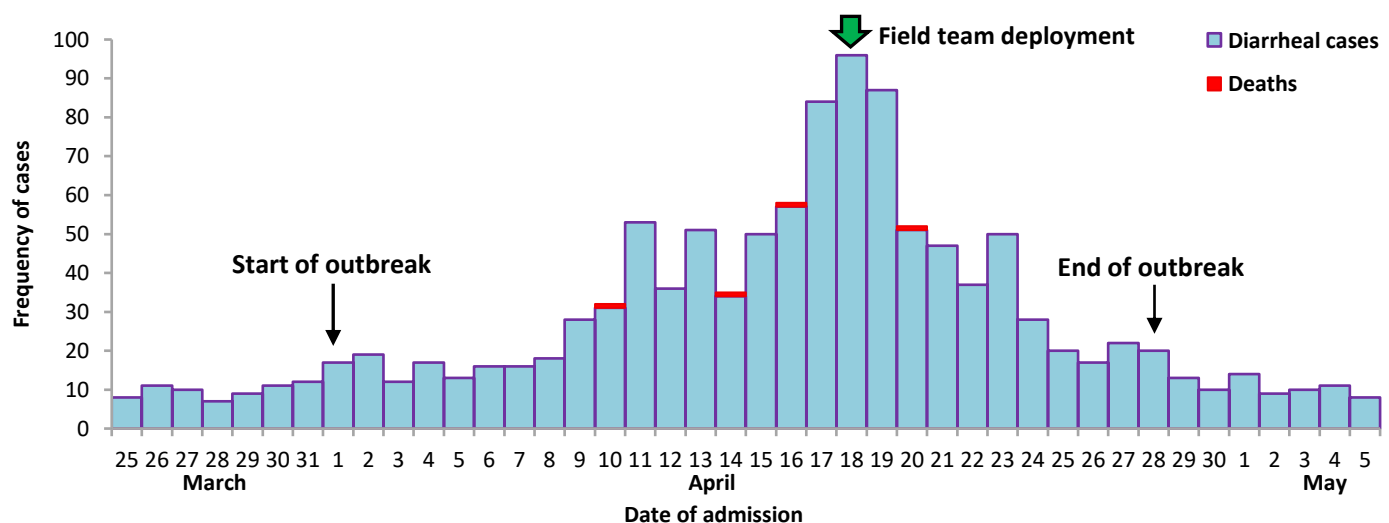


Figure 4. Daily admitted diarrheal cases in Bakerganj Sub-district Hospital, Barisal District, Bangladesh, 25 Mar–5 May 2021 (n=1,027).

Analytic Epidemiology

We enrolled 198 participants in the case-control study (66 cases, 132 controls). Cases were classified based on clinical presentation without laboratory confirmation. Cases and controls were comparable in terms of age, gender, occupation, and household income distribution. Among 66 cases, 20 (30%) were aged over 50 years and

9 (14%) were aged 0–9 years. Females comprised 56% of all cases. Housewife was the most common occupation (27%) and 82% had a monthly income of ≤15,000 Bangladeshi taka (approximately 125 USD) (Table 1). As shown in Table 2, of the 10 cases who used non-tube well surface water for drinking, 100% did not treat it first, compared to 80% (4/5) of controls. No participant in either group received OCV.

Table 1. Demographic characteristics of case-control study participants, Bakerganj Sub-district, Barisal District, Bangladesh, 2021.*

Characteristics	Cases (n=66) n (%)	Controls (n=132) n (%)	Total
Age group (years)			
0–9	9 (14)	1 (1)	10 (5)
10–19	6 (9)	10 (8)	16 (8)
20–29	7 (11)	25 (19)	32 (16)
30–39	10 (15)	38 (29)	48 (24)
40–49	14 (21)	15 (11)	29 (15)
≥50	20 (30)	43 (32)	63 (32)
Gender			
Male	29 (44)	74 (56)	103 (52)
Female	37 (56)	58 (44)	95 (48)
Occupation			
Businessperson	7 (11)	14 (11)	21 (11)
Laborer	4 (6)	19 (14)	23 (12)
Farmer	12 (18)	14 (11)	26 (13)
Government officer	0 (0)	2 (1)	2 (1)
Housewife	18 (27)	48 (36)	66 (33)
Private employee	3 (5)	5 (4)	8 (4)
Student	10 (15)	13 (10)	23 (12)
Others	6 (9)	8 (6)	14 (7)
Unemployed	6 (9)	9 (7)	15 (7)
Income (Bangladeshi taka-BDT)			
<10,000 BDT	23 (35)	52 (40)	75 (38)
10,000–15,000 BDT	31 (47)	54 (41)	85 (43)
>15,000 BDT	10 (15)	23 (17)	33 (17)
Unknown	2 (3)	3 (2)	5 (2)

*No participants received cholera vaccination.

Table 2. Source and use of water among the study participants in Bakerganj Sub-district, Barisal District, Bangladesh, 2021.

Purpose of water use	Cases, n (%)				Controls, n (%)			
	Water source				Water source			
	Tube well		Others*		Tube well		Others*	
	Purified	Not purified	Purified	Not purified	Purified	Not purified	Purified	Not purified
Drinking	8 (15)	48 (85)	0 (0)	10 (100)	37 (29)	90 (71)	1 (20)	4 (80)
Overnight fermented cooked rice	15 (88)	2 (12)	43 (88)	6 (12)	11 (73)	5 (27)	83 (72)	33 (28)
Washing fruit and vegetables	23 (88)	3 (12)	35 (87)	5 (13)	44 (70)	19 (30)	50 (72)	19 (28)
Washing hands	3 (9)	29 (91)	5 (15)	29 (85)	14 (26)	39 (74)	24 (30)	55 (70)
Ablution	2 (7)	26 (93)	6 (16)	32 (84)	13 (29)	32 (71)	25 (29)	62 (71)
Washing utensils	1 (4)	26 (96)	7 (18)	32 (82)	12 (18)	56 (82)	34 (26)	96 (74)

*Pond, canal, and river.

Children aged 0–9 years had the highest risk of illness (AOR 33.7; 95% confidence interval (CI) 3.9–287.0), while individuals aged 40–49 years also showed an elevated risk (AOR 3.4; 95% CI 1.3–8.5), with the 20–39 years age group serving as the reference category. Females had approximately twice the risk of diarrhea compared to males (AOR 2.0; 95% CI 1.0–3.9). Drinking water from sources other than tube wells was strongly

associated with illness (AOR 11.6; 95% CI 2.4–56.3). Consumption of overnight fermented rice using untreated surface water (AOR 2.5; 95% CI 1.1–5.3) and performing ablution using untreated surface water (AOR 2.4; 95% CI 1.0–5.9) were also independently associated with increased risk of diarrhea. Using surface water treated by aluminum potassium sulfate was found to be protective (AOR 0.3, 95% CI 0.1–0.7) (Table 3).

Table 3. Risk factors analysis in case-control study in Bakerganj Sub-district, Barisal District, Bangladesh, 2021.

Factor	Cases	Controls	Crude OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value
Age group (years)						
0–9	9	1	28.5 (4.7–7.5)	0.002	33.7 (3.9–287.0)	0.001
10–19	6	10	2.2 (0.6–7.0)	0.210	2.0 (0.6–6.6)	0.212
20–39	17	63	Ref	-	Ref	-
40–49	14	15	3.4 (1.3–8.6)	0.011	3.4 (1.3–4.3)	0.008
≥50	20	43	1.7 (0.8–3.7)	0.154	1.9 (0.9–4.3)	0.089
Gender						
Female	29	74	1.6 (0.9–2.9)	0.103	2.0 (1.0–3.9)	0.049
Male	37	58	Ref	-	Ref	-
Drinking other than tube well water						
Yes	9	2	10.2 (2.15–49.0)	0.003	11.6 (2.4–56.3)	0.002
No	57	130	Ref	-	Ref	-
Using untreated surface water to prepare fermented rice						
Yes	17	16	2.5 (1.2–5.4)	0.018	2.5 (1.1–5.3)	0.029
No	49	116	Ref	-	Ref	-
Washing fruits and vegetables using untreated surface water						
Yes	9	9	2.1 (0.8–5.8)	0.127	2.5 (0.9–6.8)	0.081
No	57	123	Ref	-	Ref	-
Using untreated surface water for ablution						
Yes	12	12	2.2 (0.9–5.8)	0.094	2.4 (1.0–5.9)	0.048
No	54	120	Ref	-	Ref	-
Using surface water treated by aluminum potassium sulfate						
Yes	8	40	0.3 (-0.1–0.7)	0.006	0.3 (0.1–0.7)	0.003
No	58	92	Ref	-	Ref	-

Ref: reference group. OR: odds ratio.

Environmental Findings

Surface water sources such as ponds, canals and rivers were inundated twice daily by the ebb and flow of tides, causing increased salination. During dry seasons, the salty water reaches higher levels inside the community surface waters. Field investigators also observed sewage leaking into canal water and residents collecting canal water for drinking, washing, and cooking (Figure 5).

Laboratory Findings

Among the 1,027 cases 75 stool samples were tested by RDT, 20 (27%) were positive for *V. cholerae*. Among 38 randomly selected samples sent for culture, 11 (29%) grew *V. cholerae*, 26 (69%) grew *E. coli*, and 1 (3%) grew *Citrobacter*. Among surface water samples, 62% (5/8) were tested positive for *V. cholerae* by culture and 61%

(11/18) were positive for fecal coliforms by membrane filtration.



Figure 5. Collection of surface water from a canal for drinking and other daily activities in Bakerganj Sub-district, Barisal District, Bangladesh, 2021.

Actions Taken

We found that the affected area depended on natural water sources for drinking and daily activities, without any water purification being employed. We had several meetings and awareness programs with the local political leaders, villagers and health administration staff to convey the preventive health messages of diarrhea and distributed water purification tablets (Halazone tablets) in the most affected areas. Department of Public Health Engineering (DPHE) and the Divisional Health Office were also involved in starting an awareness campaign. With the help of the local authority, we also ensured safe drinking water from various sources during the period of the outbreak.

Discussion

Diarrhea remains a major cause of childhood morbidity and mortality in the developing world, causing substantial burden on health systems, especially during outbreaks.²² During the outbreak in Barisal Division of Bangladesh, a sudden surge in hospital admissions placed considerable strain on the healthcare system. The abrupt increase in cases disrupted the overall supply chain and challenged hospital capacity.

Spatiotemporal analysis of diarrheal disease in Bangladesh showed that water scarcity and high temperatures during the dry season are strongly associated with increased incidence.²³ In coastal areas, diarrheal disease peaks during the dry pre-monsoon season and is associated with water scarcity, salt water intrusion, contamination of groundwater with *V. cholerae*, and reliance on alternative drinking water sources.¹⁴ These findings are consistent with previous evidence that saline intrusion and tidal flooding, provide favorable ecological conditions for *V. cholerae*.^{24,25} The clustering of cases in Bakerganj Sub-district, accounting for nearly three-quarters of all hospital admissions (Figure 2), indicates localized transmission dynamics, as ponds and canals are flooded by saline-rich water twice a day due to the tidal ebbs and flows.

About 84% of cases in our study had an average monthly income of 125 USD, indicating low socio-economic status. Another study showed that the financial burden is highest on the poorest households and, in Bangladesh, the average inpatient treatment cost per patient was 26.80 USD, which is almost 20% of the monthly income in our study.²⁶ Age and sex-specific patterns observed in this study, including higher infection rates among children and older adults, are

similar to those reported in a previous study.²⁷ Greater vulnerability among females reflects diverse exposure routes linked to domestic water use, food preparation, and hygiene practices. In Bangladesh, women are primarily responsible for domestic water collection, food preparation, and household hygiene, thereby increasing their exposure to potentially contaminated water and food. In addition, limited access to safe water and sanitation in low-income households may further exacerbate the risk for women.

Cholera is known to cause moderate to large outbreaks and commonly affects children under five years old.^{28,29} These outbreaks have a case fatality rate of 0.1%.²⁹ In Bakerganj, during the outbreak from 1 Apr 2021, there were four deaths out of 1,027 cases due to cholera which resulted in a case fatality rate of 0.4%. All deaths occurred in children under the age of 10, and every child passed away at home. The children who died lived in very remote areas, surrounded by rivers and canals. The roads are narrow and unpaved, and most people travel by bicycle or paddle rickshaws. As a result, travelling from home to the nearest hospital is time-consuming. Many families first seek help from local village pharmacists instead of going to the hospital. Moreover, we found that both controls and cases had not received the OCV and there was no cholera vaccination program in Barisal. Vaccination for high-risk groups can prevent diarrheal diseases such as cholera in endemic areas.³⁰ In Chandpur, another coastal district of Bangladesh, local health authorities launched a pilot project for cholera vaccination. Cholera transmission has nearly been eliminated in the Matlab Sub-district of Chandpur, despite a continuing high cholera burden in many parts of Bangladesh.³¹ Cholera transmission could be controlled in endemic areas by achieving 50% coverage using OCV.³²

The investigation identified unsafe drinking water sources and the absence of water purification practices as key predictors of diarrheal illness, underscoring persistent water safety challenges in low-income coastal settings. This observation is consistent with earlier studies linking behavioral factors such as the use of contaminated water and inadequate hygiene to diarrheal outbreaks, including cholera.³³ Previous evidence also indicates that water plays a central role in cholera transmission in coastal Bangladesh.³⁴ In the present study, laboratory confirmation of *V. cholerae* in both stool and water samples provides strong evidence that contaminated water served as the primary vehicle of transmission.

In coastal areas of Bangladesh, tube wells are the main source of drinking water with canal and river water as alternate sources.³⁵ People living in these areas usually treat surface water with aluminium potassium sulfate (Fitkiri), Halazone tablets, or simply by boiling it. Fitkiri and Halazone tablets are effective chemical treatments for water purification when used correctly. Fitkiri produces higher antimicrobial activity than other alum and Halazone tablets are used in outbreaks or emergency conditions for water purification.^{36,37} In the affected area, Halazone tablets were distributed. Proper training on effective water treatment using Halazone tablets and Fitkiri was provided, as these are readily available in coastal areas.

During the dry season, coastal districts in the south and the river corridors are vulnerable to cholera and other diarrheal diseases.³⁸ Elevated ambient temperatures are positively associated with increased incidence of diarrheal diseases, particularly among populations with lower socioeconomic status and inadequate sanitation facilities.³⁹ Consistent with these findings, the majority of diarrhea cases in our setting were reported during the hot summer months, whereas the lowest rates of diarrhea-related hospitalizations occurred during the monsoon season.⁶ Our analysis further revealed that diarrheal outbreaks typically emerge during the hot and dry pre-monsoon period and gradually decline with the onset of the monsoon rains.

Limitations

The descriptive analysis was based on hospital admission data, not community cases. We therefore assumed that the community had more cases than the reported number. We selected the households by systematic random sampling; however, at the household level, we chose the cases conveniently if there was more than one case in each household, which could introduce selection bias. To minimize this, future studies could include a community-based case finding and randomly select cases within households. Information bias was addressed by using a standardized, pre-tested questionnaire and trained interviewers; however, the possibility of recall errors and misclassification of exposures remains, particularly for self-reported symptoms and risk factors.

Public Health Recommendations

In Barisal, local health and other local government authorities should conduct mass awareness programs among those living in coastal areas before the pre-monsoon season. In the short-term, the health authority should distribute adequate water

purification tablets and oral rehydration saline to the community before every monsoon season. Provision of aluminum potassium sulfate and training on how to use it for water purification is also recommended. In the long term, we recommend residents harvest rainwater, establish water treatment plants to desalinate the saline water, and ensure adequate and productive deep tube wells. OCV could also be introduced in Barisal, as evidence from similar coastal districts in Bangladesh shows that it has successfully reduced the cholera burden.

Conclusion

Diarrhea is a major cause of death, especially among young children in low-income countries and is endemic in the southern coastal districts of Bangladesh.⁷ We conclude that diarrheal outbreaks typically occur from mid-February to mid-June, peaking in mid-March to mid-April. To be effective, preventive measures must begin well before February. Strengthening integrated disease surveillance in Barisal is paramount, as the early detection of this outbreak through health media monitoring, rather than routine surveillance, highlights existing gaps in the surveillance system. Enhanced surveillance systems should be prioritized to enable timely detection and response. Increased access to ground water, providing health awareness, and supply of water treatment materials for a safe water supply are essential preparatory measures for prevention of diarrheal outbreaks in coastal areas during dry seasons.

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Author Contributions

Md. Jahidur Rahman: Conceptualization, methodology, investigation, data curation, formal analysis,

visualization, writing—original draft, writing—review & editing. **Mallick Masum Billah:** Methodology, visualization, writing—review & editing. **Mahbubur Rahman:** Methodology, visualization, writing—review & editing. **Alden Keith Henderson:** Validation, methodology, visualization, writing—review & editing. **Immamul Muntasir:** Data curation, formal analysis. **Subrota Malakar:** Data curation, formal analysis. **Dipankar Das:** Data curation, formal analysis. **Ahmed Nawsher Alam:** Methodology, visualization, writing—review & editing. **Zakir Hossain Habib:** Methodology, visualization, writing—review & editing. **Tahmina Shirin:** Funding acquisition, resources, supervision, writing—review & editing.

Ethical Approval

IEDCR is the mandate authority of outbreak investigation. This study was done as an emergency outbreak response, therefore ethical approval was exempt.

Informed Consent

We obtained informed written consent from all the study participants before they were enrolled into the study.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

No conflicts of interest by all authors.

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Declaration of Generative-AI and AI-assisted Technologies in the Writing Process

This writing process was researched and written entirely by human effort, without the use of generative AI or AI-assisted technologies.

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