

The Temporal and Spatial Patterns of Cholera Outbreaks in the Rohingya Refugee Camps, Cox's Bazar, Bangladesh

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Cite this article as: Otieno O. D., Khan M. F., Sabbir H. S., Apolot R., Toha Bhuiyan, Kaddu S. S., Abiodun P. The Temporal and Spatial Patterns of Cholera Outbreaks in the Rohingya Refugee Camps, Cox's Bazar, Bangladesh. *Texila Int J Public Health*. 2026;14(3).
<https://doi.org/10.21522/TIJPH.2013.14.03.Art008>

Received: 26.06.2026

Accepted: 30.07.2026

Published: 30.09.2026

Article Type: Original Research

Abstract *Cholera remains a major public health threat in humanitarian settings such as the Rohingya refugee camps of Cox's Bazar, Bangladesh, which are characterised by congestion, inadequate water and sanitation, and overstretched health services. This study analysed the temporal and spatial patterns of cholera in the camps to identify seasonal variation and distribution across camps and to inform control. We used secondary data from the World Health Organization's Early Warning, Alert and Response System (EWARS), sentinel surveillance, and laboratory surveillance to construct annual weekly trend lines and epidemic curves for acute watery diarrhoea and culture-confirmed cholera, and to map case distribution across the 33 camps from 2018 to 2026. Syndromic surveillance showed year-round acute watery diarrhoea transmission with multiple non-stable seasonal peaks and a steady decline over seven years, from about 231,000 cases in 2018 to about 122,000 in 2025. Laboratory surveillance indicated that cholera was endemic, characterized by recurrent upsurges; the largest outbreak occurred in 2024 with 534 culture-confirmed cases. The dominant cholera peak occurred in the post-monsoon period (mid-September to December), diverging from the April–June pre-monsoon peak historically reported for south-eastern Bangladesh. Transmission was largely sporadic across camps without persistent hotspots, except during the 2021 and 2024 outbreaks, and shifted over time from early Teknaf-based coastal camps to the densely populated inland-located Ukhiya-based camps. These findings indicate a need to update earlier seasonality evidence and to target preventive water, sanitation, hygiene and vaccination interventions to the post-monsoon period and the high-density Ukhiya camps.*

Keywords *Cholera, Cox's Bazar, Rohingya Refugees, Seasonality, Spatial Epidemiology, Vibrio Cholerae.*

Introduction

Cholera remains a major global public health problem, disproportionately affecting low- and middle-income countries and humanitarian settings [1]. It is an acute diarrhoeal disease caused by the bacterium *Vibrio cholerae* and is transmitted through the ingestion of food or water contaminated with faecal matter; common sources include unsafe drinking water and contaminated or undercooked food, including shellfish [2]. Without prompt treatment, severe cholera can kill within hours through profuse watery diarrhoea and dehydration [1]. Globally, an estimated 1.3 to 4.0 million cases and 21,000 to 143,000 deaths occur each year, although the true burden is under-ascertained [2, 3].

Seven cholera pandemics have occurred since 1817; the seventh, caused by the El Tor biotype, began in 1961 and continues today [4]. The Bay of Bengal has historically been a major hub for global cholera spread, having seeded six of the seven pandemics [5]. Approximately 1.3 billion people are at risk worldwide, including in Bangladesh, where transmission is persistent; surveillance compiled by the World Health Organization (WHO) from 45 countries reported 535,321 cases and 4,007 deaths in 2023 [6]. The recent global resurgence of cholera has been linked to conflict, climate-related disasters, displacement, and chronic under-investment in water, sanitation and hygiene (WASH) [7].

The WHO defines cholera as endemic when confirmed cases occur in at least three of the previous five years [8]. In Bangladesh, cholera is endemic with year-round transmission and seasonal outbreaks. Long-running surveillance at the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) in Dhaka has described peaks before and after the monsoon, with lower incidence during cooler months and the height of the monsoon [9]. Importantly, the literature reports geographically distinct peak seasons: in

northern Bangladesh, transmission peaks in October and November, whereas in the south, including Cox's Bazar, where Rohingya refugee camps are situated, earlier studies described a peak from March to April [10]. Foodborne-illness surveillance by icddr,b and the Institute of Epidemiology, Disease Control and Research (IEDCR) reported about 8% culture-confirmed cholera among diarrhoeal specimens in Cox's Bazar, designating the district a high-transmission area [11].

In August 2017, approximately 700,000 Rohingya refugees fled targeted violence in Myanmar and entered Cox's Bazar, and the new wave of influx in 2024 has been estimated at 150,000 refugees arriving in camps, bringing the total displaced population to roughly 1.2million across 33congested camps in the Ukhiya and Teknaf sub-districts by 30 June 2026 [12]. Rapidly constructed shelters and spontaneous settlements on hilly, deforested terrain were vulnerable to monsoon flooding, landslides, and storm surges that repeatedly damaged WASH infrastructure [13]. Limited sanitation, suboptimal hygiene, high acute malnutrition and initially limited cholera vaccination increased vulnerability to acute watery diarrhoea (AWD) and recurrent cholera outbreaks from 2018 onward [14].

Following the influx and upsurge of communicable diseases, WHO, in collaboration with the Civil Surgeon's Office, the Refugee Relief and Repatriation Commissioner and the Health and WASH Sectors, established an Early Warning, Alert and Response System (EWARS) for priority conditions, including cholera [15]. A multi-layered surveillance architecture—combining community-based surveillance, indicator-based syndromic surveillance, sentinel-site rapid diagnostic testing and laboratory culture confirmation—supports early detection, investigation and response [16]. Despite this system and sustained humanitarian investment, cholera has persisted and periodically surged, indicating that the drivers of transmission remain

incompletely understood [9]. This study, therefore, analysed the temporal and spatial patterns of AWD and culture-confirmed cholera in the camps from 2018 to 2026, intending to characterise seasonal variation and spatial distribution and compare current seasonality with previously reported regional patterns to inform context-specific control.

Materials and Methods

Study Site

The study was conducted in the 33 officially designated Rohingya refugee camps of Cox's Bazar district, south-eastern Bangladesh, which host approximately 1.2 million displaced persons across the Ukhiya and Teknaf sub-districts. Twenty-five camps are in Ukhiya Upazila, including the Kutupalong mega-settlement, and the remaining eight are in Teknaf, several of which border the Bay of Bengal. The district experiences a tropical monsoon climate with a pronounced wet season between June and September, during which the camps are exposed to heavy rainfall, flooding and landslides that periodically damage WASH infrastructure [13].

Data Sources

Secondary data generated through the WHO's Early Warning and Alert Response System (EWARS), sentinel testing/surveillance, and laboratory surveillance were extracted and re-analysed. Weekly AWD counts from indicator-based syndromic surveillance and weekly culture-confirmed cholera counts from laboratory surveillance, confirmed by the IEDCR field laboratory in Cox's Bazar Medical College, were obtained, reviewed and synthesised for 2018 to 2026. A camp-by-year matrix of culture-confirmed cases across the 33 camps was used for the spatial analysis. Meteorological context was drawn from Bangladesh Meteorological Department records for the Cox's Bazar and Teknaf stations.

Statistical Methods

Weekly cholera and AWD data were cleaned and converted into complete weekly time series, with epidemiological weeks lacking reported cases retained as zero-case weeks to preserve continuity. Annual weekly trend lines and epidemic curves were plotted on a common scale to enable comparison across years. Cases were aggregated to annual and monthly totals and classified into four climatic seasons—winter (December–February), pre-monsoon (March–May), monsoon (June–September), and post-monsoon (October–November)—to characterise seasonal structure. For the spatial analysis, sentinel-site and laboratory data were used to construct a camp-by-year case matrix and to compare the Ukhiya-based and Teknaf-based camp clusters over time. Descriptive results were cross-checked against operational WHO epidemiological bulletins to confirm fidelity. Analyses were conducted using standard statistical software.

Results

Temporal Trends in Acute Watery Diarrhoea

Indicator-based syndromic surveillance indicated year-round AWD transmission with multiple peaks of varying intensity (Figure 1). The highest activity occurred between August and December (epidemiological weeks 35–50; post-monsoon), with a second, moderate peak from mid-April to June (epidemiological weeks 17–24; pre-monsoon); transmission decreased from mid-January to mid-April and during July and August. The overall AWD burden declined steadily across seven years, from approximately 231,000 cases in 2018—when WASH services were least developed—to approximately 122,000 in 2025, a reduction of nearly half (Table 1). This decline is consistent with the maturation of WASH infrastructure, hygiene promotion, and health-service coverage over time.

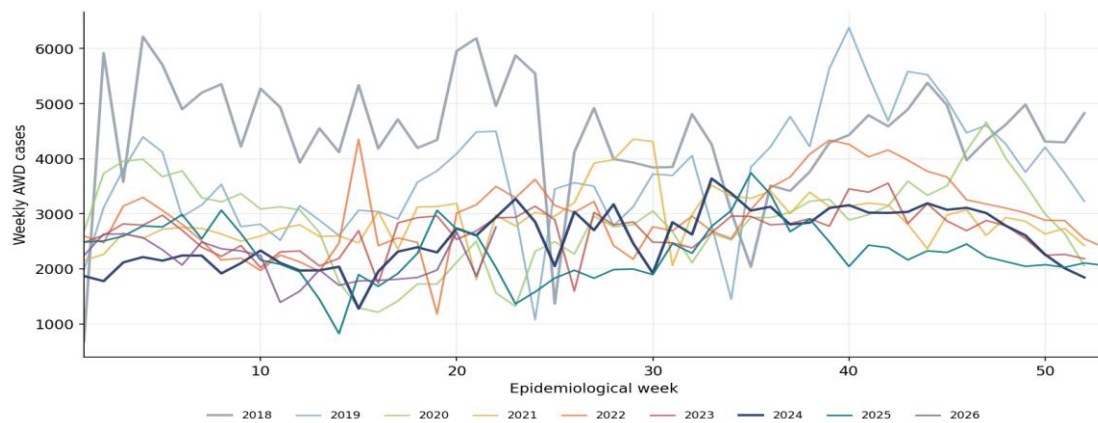


Figure 1. Annual Weekly Trends of Acute Watery Diarrhoea, Rohingya Refugee Camps, 2018–2026

Table 1. Annual Acute Watery Diarrhoea and Culture-confirmed Cholera Burden, Rohingya Refugee Camps, 2018–2026

Year	AWD cases	Confirmed cholera	Notable feature
2018	231,378	—	Highest AWD; pre-confirmation baseline
2019	193,083	183	First major confirmed cholera year
2020	147,689	5	Pandemic restrictions; reduced testing
2021	151,861	136	Resurgence: outbreak declined, reactive OCV campaign in October and November 2021
2022	157,945	70	Sustained endemic transmission
2023	138,903	81	Ad hoc waterline-linked outbreak
2024	132,522	534	Largest outbreak on record
2025	121,951	59	Lowest AWD; post-outbreak decline triggered by the reactive OCV campaign
2026*	47,063	8	To epidemiological week 22

*2026 data are partial (to epidemiological week 22). AWD declined steadily, while confirmed cholera cases fluctuated episodically after the reactive OCV outbreak campaign in January 2025. OCV = oral cholera vaccine.

Temporal Trends in Culture-Confirmed Cholera

Laboratory surveillance indicated endemic cholera, with cases reported year-round for more than three years (Figure 2). Confirmed cases numbered 183 in 2019, fell to 5 in 2020—a year of COVID-19 pandemic-related restrictions and reduced testing—then rose to 136 in 2021 before settling at 70 and 81 in 2022 and 2023, respectively (Table 1). In 2024, the count surged to 534 confirmed cases, documenting the largest outbreak on record due

to more than three years of waned population immunity after the 2021 OCV campaign. The 2025 outbreak (59 cases) continued the large outbreak in 2024, which was contained in January by the scale-up of the oral cholera vaccine (OCV) campaign. The highest annual peak consistently occurred between epidemiological weeks 39 and 50 (mid-September to December; post-monsoon), with a milder peak in epidemiological weeks 25 to 30 (mid-June to July; monsoon). More than five outbreaks were observed over the period, except in 2020.

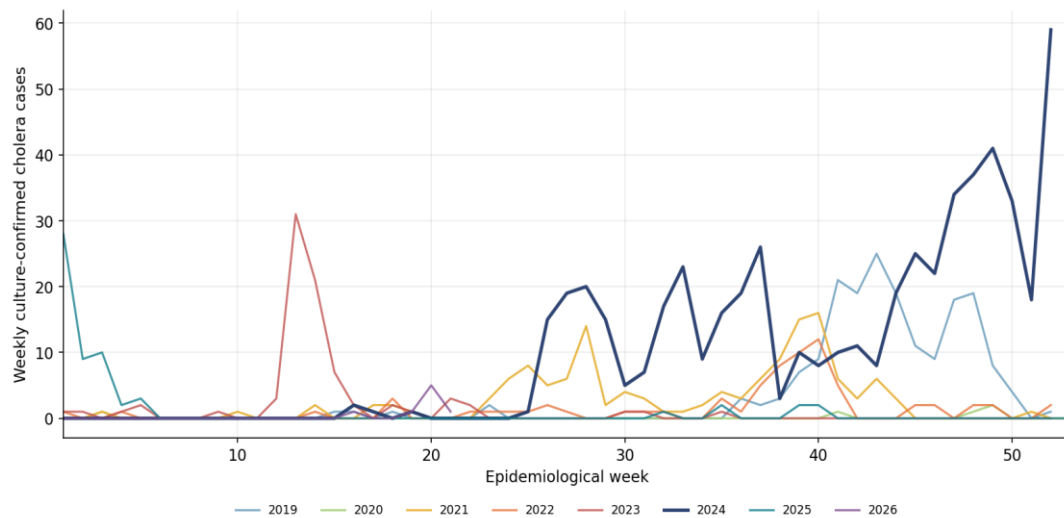


Figure 2. Weekly Culture-confirmed Cholera Cases by Year, Rohingya Refugee Camps, 2019–2026

Superimposing the AWD and culture-confirmed cholera curves (Figure 3) showed similar peak timing (epidemiological weeks 35–46) in 2019, 2021, and 2024, with variation in other years. The 2023 event was an ad hoc outbreak linked to waterline contamination in two camps (Camps 2W and 6) and was reportedly contained within three weeks (epidemiological weeks 13–15) by a joint Health and WASH response. The most intense

transmission occurred during the 2024 outbreak, from epidemiological week 44 of 2024 to early 2025, aligning with the post-monsoon period. The divergence between the steadily declining AWD trend and the episodically surging cholera trend indicates that confirmed cholera transmission follows a dynamic distinct from that of the general diarrhoeal disease burden.

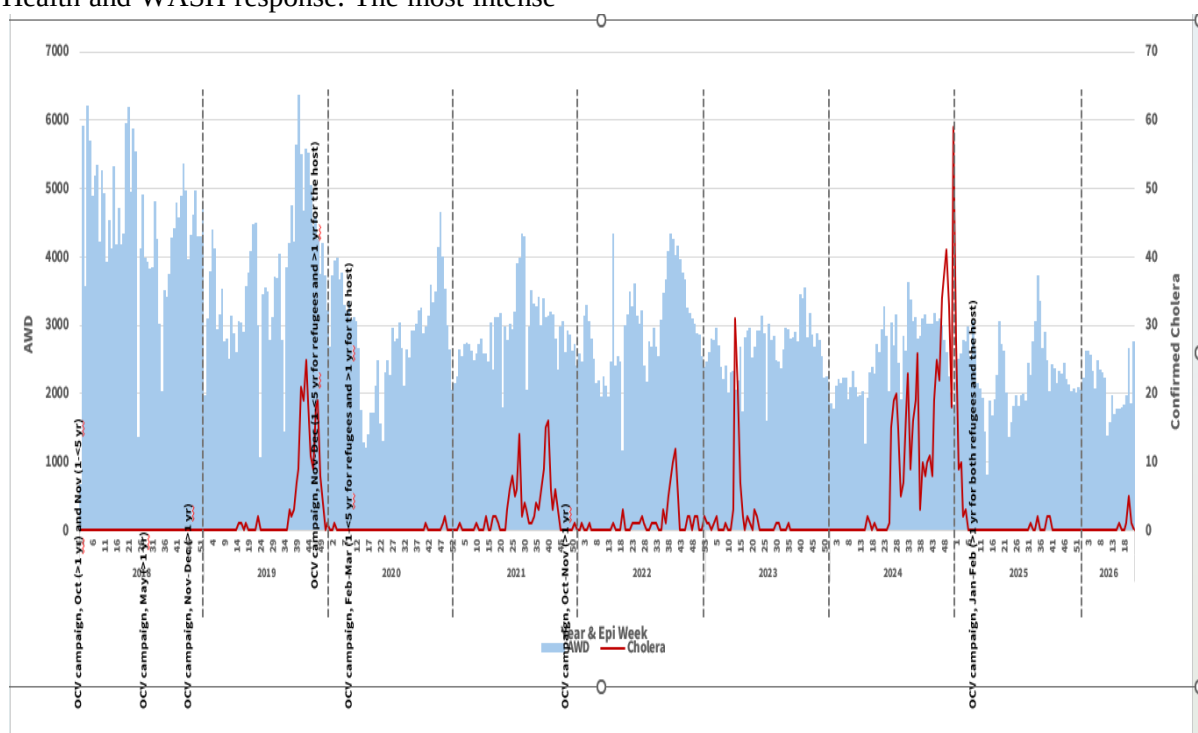


Figure 3. Superimposed Monthly Trends of Acute Watery Diarrhoea, Culture-confirmed Cholera and OCV Campaigns Conducted from 2018–2026

Seasonal Distribution

When confirmed cases were aggregated by climatic season, the post-monsoon season carried the highest mean monthly burden (27.5 cases per month), more than double that of the monsoon (12.8) and winter (11.0) seasons, and more than six times that of the pre-monsoon season (4.4) (Table 2). The post-monsoon and

monsoon seasons together accounted for the majority of confirmed cases. Negative binomial regression confirmed that the post-monsoon season carried an approximately six-fold higher cholera case rate than the pre-monsoon season. This post-monsoon dominance diverges from the April–June pre-monsoon peak historically described for south-eastern Bangladesh by scientists [10].

Table 2. Seasonal Distribution of Culture-confirmed Cholera Cases, Rohingya Refugee Camps, 2019–2025

Season	Total cases	Mean cases/month	Median cases/month	Share of cases
Winter (Dec–Feb)	232	11.0	1.0	21.7%
Pre-monsoon (Mar–May)	92	4.4	1.0	8.6%
Monsoon (Jun–Sep)	359	12.8	2.0	33.6%
Post-monsoon (Oct–Nov)	385	27.5	4.5	36.0%

The post-monsoon season carries the highest mean monthly burden, indicating a dominant post-monsoon peak that diverges from the historically reported March–April peak for south-eastern Bangladesh.

Spatial Distribution

The camp-by-year analysis showed that, in most years, cases were distributed sporadically across many camps without persistent, year-on-year hotspots—a pattern consistent with widespread environmental seeding rather than a

single fixed-point source (Figure 4 and 5). The principal exception was the 2024 outbreak, during which cases clustered intensely in a subset of densely populated Ukhiya camps. Cumulatively, a minority of camps accounted for a disproportionate share of confirmed cases.

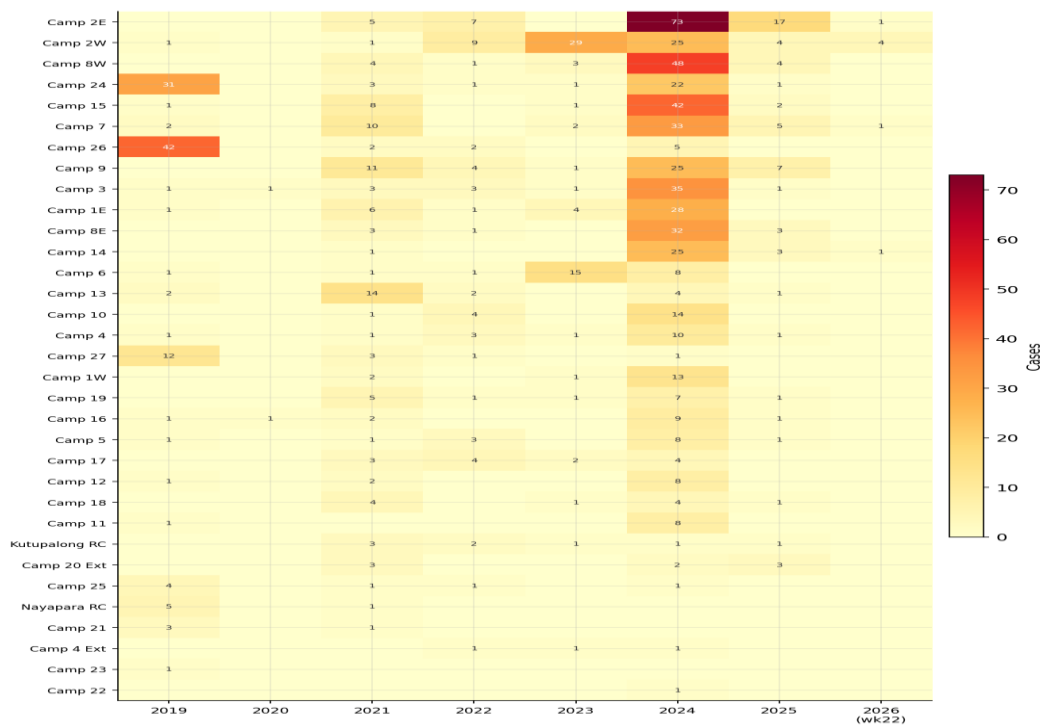


Figure 4. Culture-confirmed Cholera Cases by Camp and Year, Rohingya Refugee Camps, 2019–2026

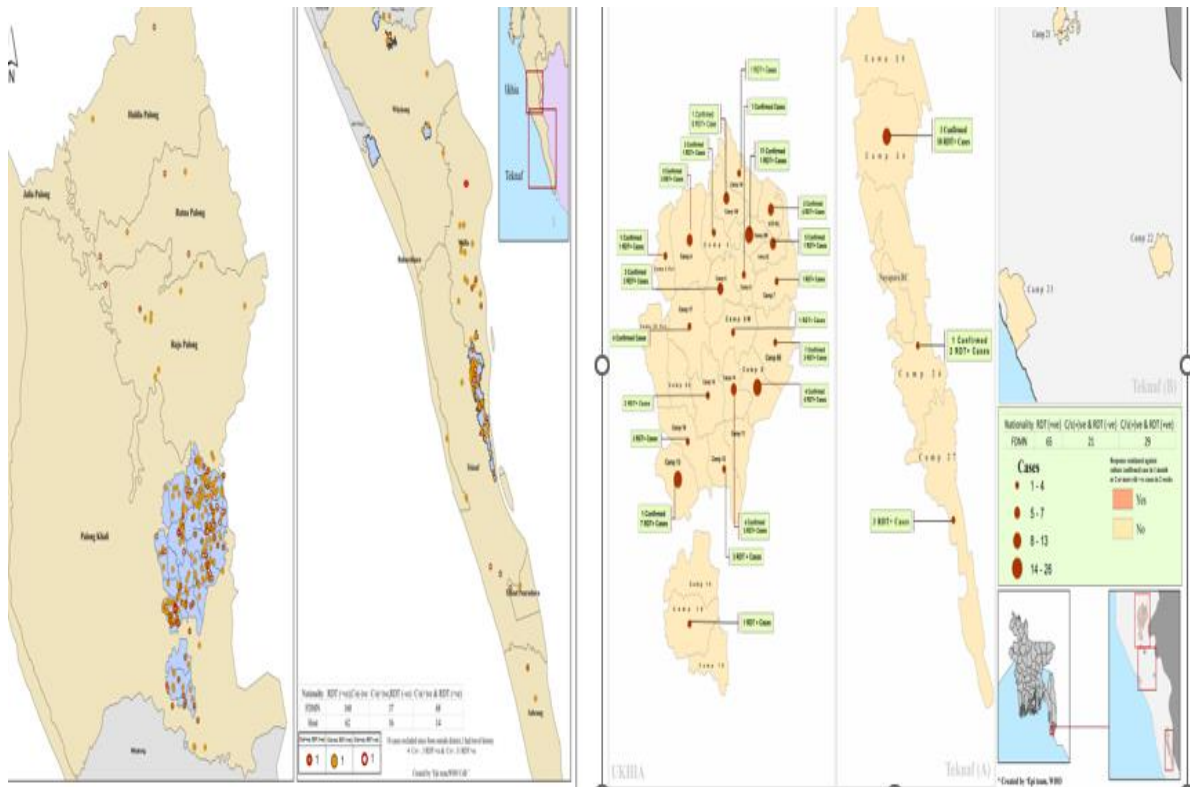


Figure 5. Distribution of Cholera Cases in Ukhiya and Teknaf-based Camps in 2021 and 2022

Aggregating cases by sub-districts/Upazilas hosting Rohingya refugee camps revealed a striking spatial dynamic (Figures 6 and 7). In 2019, confirmed cholera was concentrated overwhelmingly in the Teknaf-based coastal camps, which recorded 98 cases compared with 14 in the Ukhiya-based camps, consistent with the proximity of these camps to the brackish coastal aquatic reservoir of *V. cholerae* [13].

From 2021 onward, the pattern reversed decisively: the Ukhiya-based camps came to dominate transmission, recording 467 confirmed cases against only 30 in the Teknaf-based camps in 2024. This shift towards the densely populated Ukhiya mega-settlement reflects the role of population density and person-to-person amplification in sustaining transmission once the pathogen is established.

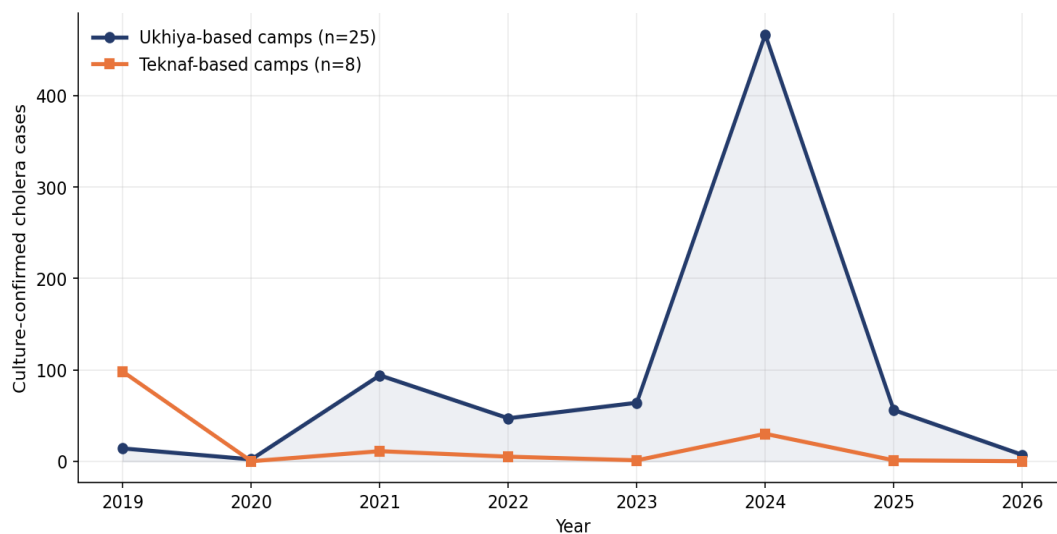


Figure 6. Distribution of Culture-confirmed Cholera Cases in Ukhiya-based Versus Teknaf-based Rohingya Refugee Camps, 2019–2026

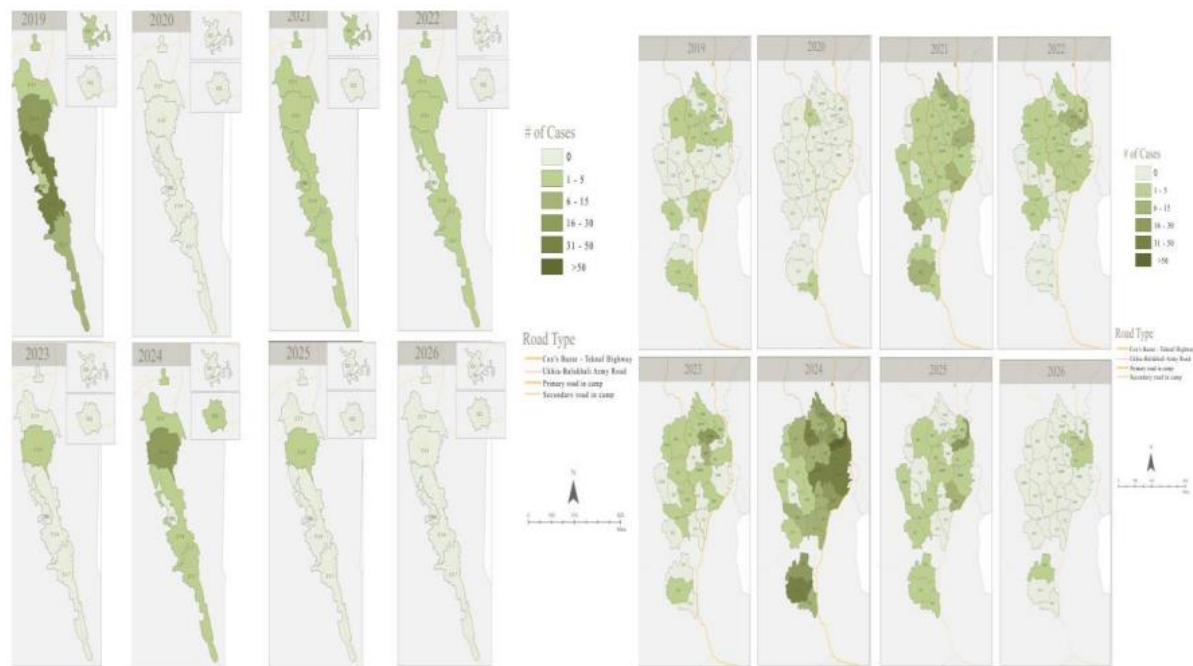


Figure 7. Distribution of Culture-confirmed Cholera Cases in Teknaf and Ukhya-based Rohingya Refugee Camps in Cox's Bazar, Bangladesh from 2019 to mid-2026

Discussion

This analysis shows that AWD transmission is year-round, while cholera is endemic with recurrent seasonal and occasional ad hoc outbreaks in the Rohingya camps. AWD peaks mainly in the pre-monsoon and post-monsoon periods and has declined steadily over seven years, consistent with maturing WASH services. Cholera transmission is also year-round, with peak activity from mid-September to December (post-monsoon). This differs from earlier published findings suggesting peak transmission in south-eastern Bangladesh from March to April [10], highlighting the need to review and update seasonality evidence for the Rohingya camps and possibly the wider Cox's Bazar district [9].

Several mechanisms may account for the apparent seasonal shift. The post-monsoon period follows the inundation, infrastructural damage, and faecal–oral contamination of the monsoon but occurs once standing water has begun to recede and human activity resumes—conditions that may favour both environmental persistence and person-to-person amplification [17, 18]. The offset between the rainfall

maximum (monsoon) and the cholera peak (post-monsoon) is the temporal signature expected if transmission is driven by the delayed consequences of monsoon flooding rather than by rainfall itself [19]. Whatever the precise mechanism, the operational implication is that preventive interventions calibrated to a pre-monsoon peak would be mistimed.

Sentinel and laboratory data suggest cholera transmission intensified between 2021 and 2024 relative to 2019–2020, despite ongoing WASH and health-sector interventions. These observations are consistent with surveillance findings reported for diarrhoea and cholera early warning among Rohingya populations [20]. Geospatial analysis indicates that transmission is generally sporadic and lacks well-defined clustering across camps, except during the large 2024 outbreak, a pattern consistent with widespread water contamination and limited persistent secondary transmission in endemic years [21]. The distinction between dominant sporadic, environmentally seeded transmission noted over the seven years and limited clustered, density-driven outbreak transmission noted in

2024 has direct implications for control: the former calls for area-wide measures, the latter for targeted, case-area interventions [22].

From the available data, cholera appears to have originated in the Teknaf-based camps bordering the Bay of Bengal during the 2019 outbreak, consistent with the role of coastal aquatic reservoirs in seeding transmission [23]. It then spread to the 25 Ukhiya-based camps, where intensified transmission has been sustained, while transmission in Teknaf slowed after 2020. This evolution—from an environmentally seeded coastal focus to a density-driven inland epidemic—implies that prevention should be both spatially and temporally targeted, directed at the highest-burden Ukhiya camps in the run-up to the post-monsoon season [24]. These findings should be interpreted considering the limitations of surveillance data, which are subject to under-ascertainment and reporting variation, and the reliance on culture confirmation, which may underestimate true incidence [25].

Conclusion

Cholera remains endemic in the Rohingya refugee camps, with year-round transmission and recurrent outbreaks, while AWD transmission is persistent across the year, coupled with multiple peaks, and has gradually declined from 2018 to mid-2025. Recent surveillance indicates that the cholera peak season has shifted from the previously reported April–June period to mid-September–December, suggesting changes in seasonal dynamics and the need to update prior evidence [10]. Cholera outbreaks intensified in 2021–2024 compared with 2019–2020, despite ongoing WASH and health-sector interventions, while AWD declined steadily. Spatial patterns are largely sporadic across camps, with notable clustering mainly during the 2024 outbreak, likely to reflect widespread water contamination [21]. Transmission appears to have begun in the Teknaf-based camps during the 2019 outbreak and to have

seeded the densely populated Ukhiya-based camps, which have sustained persistent, intensified annual transmission. These findings support context-specific prevention—reactive oral cholera vaccination and WASH intensification timed to precede the post-monsoon season and targeted to the high-density camps [24, 26]. Further research, including molecular characterisation of circulating strains and time-series modelling, is needed to strengthen early warning and control [27, 28].

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgements

The authors thank Sami Momtahir, Rafi Abdur, and Islam Md Sahidul of the World Health Organization Health Emergencies Programme in Cox's Bazar, who assisted with data cleaning and preparation of the graphs for this manuscript; the Civil Surgeon's Office, Refugee Relief and Repatriation Commission (RRRC) for collaborative support and authorizing the use of the refugee data.

Ethical Approval

The study used routine, de-identified surveillance, laboratory, and meteorological data generated through the operations of the World Health Organization, the Institute of Epidemiology, Disease Control and Research, and the Bangladesh Meteorological Department, used with appropriate authorization for academic purposes. Ethical oversight was sought from the relevant national and institutional review bodies (local IRB at Cox's Bazar Medical College and Refugee Relief and Repatriation Commission).

Author Contributions

O. D. Otieno conceptualised the study, curated and analysed the data, and drafted the manuscript. M. F. Khan and H. S. Sabbir contributed to data acquisition, surveillance

data review, and critical revision of the manuscript. Toha M R. Apolot, K. S. Kaddu and P. Abiodun contributed to the final revision of the manuscript. All authors read and approved of the final manuscript.

Data Availability

The surveillance, laboratory and meteorological datasets analysed in this study were generated through the routine operations of the World Health Organization Health Emergencies Programme in Cox's Bazar, the

Institute of Epidemiology, Disease Control and Research, and the Bangladesh Meteorological Department. Aggregated data supporting the findings are available from the corresponding author on reasonable request and subject to the data-sharing policies of the responsible institutions.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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