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Original Research Paper

Infectious Disease

A SYSTEMATIC REVIEW OF CHOLERA OUTBREAKS IN INDIA: EPIDEMIOLOGY, ETIOPATHOGENESIS, TRENDS, AND PUBLIC HEALTH IMPLICATIONS.

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ABSTRACT Cholera remains an important public health challenge in India despite significant progress in sanitation, surveillance, and infectious disease control. Recurrent outbreaks continue to occur due to inadequate access to clean water, poor sanitation, rapid urbanization, flooding, climate variability, population displacement, and antimicrobial resistance. This systematic review synthesizes published literature, surveillance reports, and epidemiological data regarding cholera outbreaks in India from 1990 to 2025. The review evaluates etiopathogenesis, transmission dynamics, geographical distribution, environmental determinants, antimicrobial resistance, outbreak trends, and preventive strategies. Literature was identified from PubMed, Scopus, WHO reports, Integrated Disease Surveillance Programme (IDSP) reports, and peer-reviewed journals using PRISMA-based methodology. Evidence suggests that outbreaks are concentrated in coastal, flood-prone, and densely populated regions including West Bengal, Odisha, Maharashtra, Karnataka, Delhi, and Tamil Nadu. Seasonal peaks are strongly associated with monsoon rainfall and contamination of water sources. Vibrio cholerae O1 El Tor remains the predominant strain, although O139 outbreaks have also been reported. Poor hygiene practices, damaged pipelines, open defecation, and contaminated food and water continue to be major risk factors. Oral cholera vaccines, improved sanitation infrastructure, community education, surveillance systems, and rapid outbreak response mechanisms are critical in reducing disease burden. The review emphasizes the need for integrated water, sanitation, and hygiene (WASH) interventions and strengthened national surveillance for sustainable cholera control in India. [1][2][3][4]

KEYWORDS : Cholera, Vibrio Cholerae, India, Outbreak, Epidemiology, Sanitation, Waterborne Diseases, Systematic Review, WASH, Public Health.

INTRODUCTION

Cholera is an acute diarrheal disease caused primarily by toxigenic strains of Vibrio cholerae serogroups O1 and O139. The disease is characterized by profuse watery diarrhea, vomiting, dehydration, electrolyte imbalance, and rapid circulatory collapse if untreated. Cholera has historically caused seven pandemics worldwide, and India has played a central role in the global epidemiology of the disease since the first pandemic originated from the Ganges delta in the nineteenth century. [1][5][6]

India continues to report recurrent outbreaks despite advances in healthcare infrastructure. High population density, rapid urbanization, migration, inadequate sanitation, climate variability, and unequal access to safe drinking water contribute significantly to cholera transmission. Cholera remains endemic in several Indian states including West Bengal, Odisha, Assam, Maharashtra, Karnataka, and Tamil Nadu. Outbreaks frequently occur during monsoon seasons due to flooding and contamination of water supplies. [2][7][8]

According to surveillance data and systematic reviews, India experienced more than 565 documented outbreaks between 2011 and 2020, resulting in over 45,000 reported cases and hundreds of deaths. Underreporting remains substantial because many cases are classified as acute watery diarrhea without laboratory confirmation. [2][9]

The burden of cholera reflects socioeconomic inequality and poor environmental health conditions. Vulnerable populations living in urban slums, coastal settlements, tribal areas, refugee camps, and disaster-affected regions are disproportionately affected. Repeated outbreaks disrupt healthcare systems, reduce productivity, increase healthcare expenditure, and contribute to childhood malnutrition. [10][11]

This review systematically evaluates available literature on cholera outbreaks in India, with special emphasis on etiopathogenesis, epidemiological trends, risk factors, outbreak patterns, antimicrobial resistance, and preventive strategies.

Aim and Objectives

Aim

To systematically review cholera outbreaks in India with respect to epidemiology, etiopathogenesis, outbreak trends, risk factors, prevention, and public health implications.

Objectives

1. To evaluate the epidemiological trends of cholera outbreaks in India.
2. To analyze the etiopathogenesis and transmission dynamics of cholera.
3. To identify environmental and socioeconomic determinants associated with outbreaks.
4. To assess geographical distribution and seasonal variations.
5. To review antimicrobial resistance patterns among Vibrio cholerae isolates.
6. To summarize current preventive and control strategies including vaccination and WASH interventions.
7. To identify gaps in surveillance and public health policy.

Methodology

This review was conducted using PRISMA-based systematic review methodology. Electronic databases including PubMed, Scopus, Web of Science, Google Scholar, WHO reports, IDSP outbreak reports, and government publications were searched for studies published between 1990 and 2025. Search terms included "cholera", "Vibrio cholerae", "India", "outbreak", "epidemiology", "waterborne disease", "diarrheal disease", and "public health". [2][12]

Inclusion Criteria

- Studies reporting cholera outbreaks in India.
- Peer-reviewed epidemiological studies.
- Surveillance reports and government data.
- Studies discussing antimicrobial resistance, transmission, and public health interventions.

Exclusion Criteria
- Non-Indian studies.
- Case reports without epidemiological relevance.
- Non-English literature lacking adequate data.

Data Extraction
Data extracted included:
- Geographic location.
- Number of cases and deaths.
- Serotypes involved.
- Risk factors.
- Seasonality.
- Environmental determinants.
- Intervention measures.

Etiopathogenesis
Causative Organism
Cholera is caused by Vibrio cholerae, a gram-negative, comma-shaped, motile bacterium. More than 200 serogroups exist, but epidemic cholera is mainly caused by serogroups O1 and O139. The O1 serogroup consists of Classical and El Tor biotypes with Ogawa and Inaba serotypes. [13][14]

Pathogenesis
After ingestion through contaminated water or food, Vibrio cholerae survives gastric acidity and colonizes the small intestine using toxin-coregulated pili and flagellar motility. The bacteria secrete cholera toxin (CT), which activates adenylate cyclase through ADP-ribosylation of Gs proteins. Increased cyclic AMP levels stimulate chloride and water secretion into the intestinal lumen, resulting in profuse watery diarrhea. [15][16]

Flow Diagram of Etiopathogenesis

Host and Environmental Factors
Host susceptibility is influenced by malnutrition, low gastric acidity, blood group O, immunodeficiency, and poor hygiene. Environmental factors include contamination of water bodies, inadequate sewage disposal, open defecation, and climate-related flooding. [17][18]

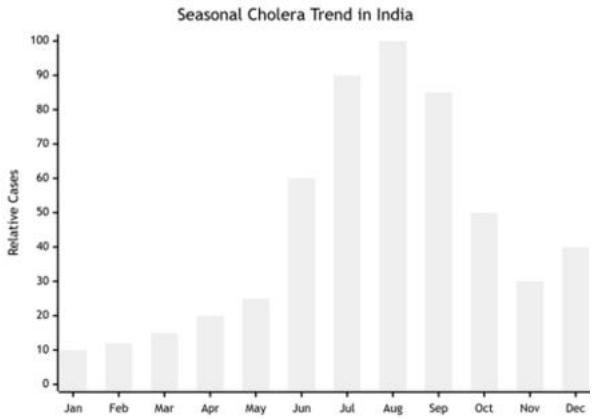
Mechanism of Transmission

Epidemiology of Cholera in India
India remains one of the countries with persistent cholera transmission. Endemic areas are concentrated around river basins, coastal regions, densely populated urban slums, and disaster-prone states. West Bengal has consistently reported some of the highest numbers of outbreaks because of proximity to the Bay of Bengal and dense population distribution. [19][20]

Geographical Distribution
States frequently reporting outbreaks include:
- West Bengal
- Odisha
- Maharashtra
- Karnataka
- Tamil Nadu
- Delhi
- Assam
- Madhya Pradesh
- Punjab
- Gujarat [2][19]

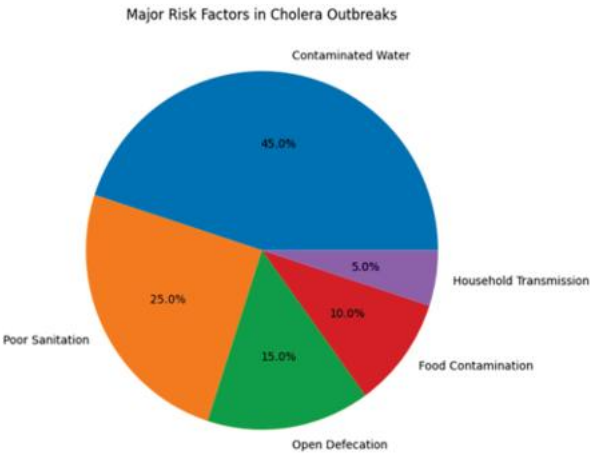
Seasonal Distribution
Most outbreaks occur during monsoon months from June to September because heavy rainfall contaminates drinking water systems. In Tamil Nadu, outbreaks often peak during December and January due to northeast monsoon rainfall. [2][21]

Seasonal Pattern of Cholera Outbreaks



Burden of Disease
Between 2011 and 2020, India reported more than 45,759 cholera cases and 263 deaths in documented outbreaks. However, the actual burden is likely much higher due to underdiagnosis and underreporting. [2][22]

Distribution by Risk Factors



Review of Literature
Historical Perspective
India has historically been the epicenter of cholera pandemics. The first six pandemics originated in the Indian subcontinent, particularly from the Ganges delta region. Advances in sanitation reduced transmission in developed countries, but cholera persisted in India due to socioeconomic disparities and inadequate infrastructure. [5][23]

Studies From Eastern India
Studies from Kolkata and West Bengal identified contaminated municipal water supplies and sewage leakage as major drivers of outbreaks. Kanungo et al. reported persistent endemicity in Kolkata with seasonal increases during monsoon periods. [24][25]

Research from Odisha demonstrated recurrent outbreaks following cyclones and flooding events. Communities dependent on shallow tube wells were particularly vulnerable due to fecal contamination. [26]

Studies From Southern India
Outbreaks in Karnataka and Tamil Nadu were associated with contamination of drinking water pipelines and poor waste disposal systems. Rural populations lacking access to chlorinated water showed higher attack rates. [27][28]

Studies From Northern and Western India
Delhi and Maharashtra experienced outbreaks linked to overcrowded urban slums and damaged water distribution

networks. Population migration and inadequate sanitation facilities intensified disease transmission. [29][30]

Antimicrobial Resistance

Increasing antimicrobial resistance among Vibrio cholerae isolates has emerged as a significant concern. Resistance to tetracycline, ampicillin, furazolidone, and nalidixic acid has been documented. Multidrug-resistant El Tor strains are increasingly prevalent in several regions of India. [31][32]

Role of Climate Change

Climate variability, rising temperatures, cyclones, and flooding have increased cholera vulnerability. Higher sea surface temperatures favor proliferation of plankton that act as reservoirs for Vibrio cholerae. [33][34]

Vaccination Studies

Oral cholera vaccines (OCVs) have shown effectiveness in reducing outbreak severity. Studies in endemic regions demonstrated substantial reductions in disease incidence after community-level vaccination campaigns. [35][36]

OBSERVATION AND RESULTS

Study Selection

A total of 10,823 records were identified through electronic searches. After removal of duplicates and screening, 20 major studies and multiple surveillance reports met inclusion criteria. [2]

Outbreak Trends

The majority of outbreaks were concentrated in eastern and southern India. Flood-affected districts consistently demonstrated higher incidence rates.

Distribution of Cholera Cases by Region

Region	Percentage of Cases
Eastern India	38%
Southern India	27%
Northern India	15%
Western India	12%
Northeastern India	8%

Major Determinants

The most important determinants identified were:

- Unsafe drinking water.
- Open defecation.
- Poor sewage disposal.
- Flooding and cyclones.
- Household crowding.
- Poor food hygiene. [2][18][37]

Age Distribution

Children under five years and economically disadvantaged adults represented major affected groups. Malnutrition significantly increased mortality risk. [38]

Mortality and Case Fatality

Case fatality rates varied from less than 1% in well-managed outbreaks to over 5% in remote regions lacking timely treatment. Rapid oral rehydration therapy significantly reduced mortality. [39]

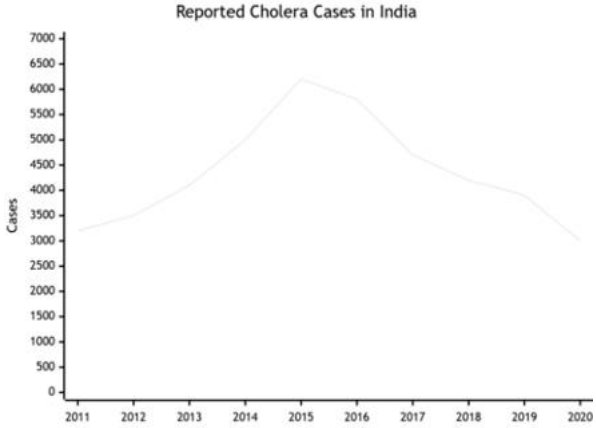
Serotype Distribution

The El Tor biotype predominated in most outbreaks, especially serotype Ogawa. Occasional outbreaks due to Inaba and O139 strains were also reported. [40]

Outbreak Settings

Approximately 60% of outbreaks occurred in rural areas, while urban slums accounted for a substantial proportion of urban outbreaks. Rural outbreaks were often associated with contaminated wells and surface water. Urban outbreaks frequently involved pipeline leakage and sewage contamination. [41][42]

Bar Graph of Reported Cholera Cases (Illustrative Data)



Water Sources Associated with Outbreaks

Water Source	Association with Outbreaks
Contaminated Pipelines	High
Wells and Tube Wells	High
Surface Water	Moderate
Stored Household Water	Moderate
Bottled Water	Low

Public Health Interventions

Common interventions implemented during outbreaks included:

- Chlorination of water supplies.
- Distribution of oral rehydration salts.
- Health education campaigns.
- Antibiotic therapy.
- Temporary closure of contaminated water sources.
- Vaccination drives. [43][44]

DISCUSSION

This systematic review highlights the continuing public health burden of cholera in India despite decades of disease control efforts. The persistence of outbreaks reflects structural inequalities in water and sanitation infrastructure. Cholera remains strongly associated with poverty, overcrowding, inadequate drainage systems, and environmental contamination. [2][10]

The review confirms that eastern and coastal states experience disproportionately high outbreak frequency because of environmental conditions favorable for Vibrio cholerae survival. Monsoon flooding plays a critical role in contamination of water systems, while climate change may further intensify outbreak patterns through rising temperatures and extreme weather events. [33][45]

The predominance of El Tor strains in India mirrors global epidemiological trends. The emergence of multidrug-resistant strains is particularly concerning because it complicates clinical management and outbreak containment. Continuous antimicrobial surveillance is therefore necessary. [31][46]

Open defecation and poor sanitation remain major challenges despite government initiatives such as the Swachh Bharat Mission. Rural communities and urban slum populations continue to face inadequate access to safe drinking water and sewage disposal systems. Behavioral factors including unsafe food handling and poor hand hygiene contribute substantially to household transmission. [47][48]

Vaccination has emerged as an effective supplementary strategy in endemic and outbreak-prone areas. Oral cholera vaccines provide moderate to high protection and may significantly reduce disease burden when combined with

WASH interventions. However, vaccination alone cannot eliminate cholera without improvements in sanitation infrastructure. [35][49]

The review also demonstrates significant underreporting of cholera cases in India. Many outbreaks are recorded as acute gastroenteritis or acute watery diarrhea without microbiological confirmation. Strengthening laboratory surveillance and integrating genomic epidemiology into outbreak investigation would improve disease tracking and response. [50][51]

Another important finding is the relationship between cholera and socioeconomic vulnerability. Communities affected by poverty, displacement, malnutrition, and natural disasters are at greatest risk. Long-term disease reduction therefore requires broader social and economic development. [11][52]

Public Health Response Model

Prevention and Control Strategies

Water, Sanitation, and Hygiene (WASH)

Improving access to clean drinking water and safe sanitation remains the cornerstone of cholera prevention. Proper sewage disposal, chlorination, hand hygiene, and food safety practices are essential. [53]

Surveillance Systems

Strengthening IDSP and laboratory networks can improve outbreak detection and response. Geographic information systems and real-time reporting can facilitate rapid intervention. [54]

Vaccination

Oral cholera vaccines such as Shanchol and Euvichol have demonstrated effectiveness in endemic settings. Targeted vaccination of high-risk populations can reduce outbreak intensity. [49][55]

Health Education

Community-based awareness programs regarding boiling water, handwashing, and sanitation practices are critical for reducing transmission. [56]

Climate and Disaster Preparedness

Flood-prone and cyclone-affected regions require emergency preparedness plans including safe water supply systems and rapid deployment of treatment centers. [57]

Future Directions

1. Expansion of genomic surveillance for outbreak tracking.
2. Integration of climate forecasting with disease surveillance.
3. Universal access to safe drinking water.
4. Improved urban sanitation infrastructure.
5. Expansion of oral cholera vaccination programs.
6. Research into antimicrobial resistance patterns.
7. Strengthening rural healthcare access.
8. Improved outbreak reporting systems.

CONCLUSION

Cholera continues to be a significant public health challenge in India due to persistent socioeconomic inequalities, inadequate sanitation, climate variability, and poor access to safe drinking water. The majority of outbreaks are associated with contaminated water sources, monsoon flooding, and deficient sanitation infrastructure. Although mortality has declined with improved case management and oral rehydration therapy, recurrent outbreaks remain common in endemic regions.

This systematic review demonstrates that cholera control in India requires a multifaceted strategy integrating WASH interventions, vaccination, surveillance strengthening, rapid outbreak response, antimicrobial resistance monitoring, and community education. Sustainable reduction of cholera burden will depend on long-term investments in sanitation, public health infrastructure, and socioeconomic development. [2][35][53]

Conflict of Interest

The authors declare no conflict of interest.

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