Original Article

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Public Health Section

Epidemiological Investigation of an Outbreak of Acute Diarrhoeal Disease in a Coastal Area in Central Kerala, India: A Cross-sectional Study

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ABSTRACT

Introduction: A disease outbreak is the occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area or season. Early detection and reporting of such events is crucial in limiting the spread of the disease and minimising its negative social and economic impact.

Aim: To explore the clinico-epidemiological features of the diarrhoeal disease outbreak in a municipal area in a coastal region of Central Kerala and to identify the factors associated with the diarrhoeal disease outbreak.

Materials and Methods: This was an epidemiological investigation conducted as a cross-sectional analytical study done in December 2022 in the coastal wards, namely ward no. 41, 42 and 43 of Alappuzha Municipality, Alappuzha, Kerala, India from where an increased number of ADD cases were reported in November 2022-December 2022. An investigator administered questionnaire was used to collect information from 191 residents. Water samples were taken from four points in the community to check the coliform count, and stool and rectal swabs for microbiological examination. Continuous variables were summarised as Mean±Standard Deviation (SD), and categorical variables as proportions. Associations were tested with the Chi-square test, and a p-value of less than 0.05 was considered statistically significant.

Results: The prevalence of ADD among children in the under-five age group in the coastal wards was 0.020 (2.1%) 95% Confidence Interval (CI): 1.2- 3.4 and in the age group above five years in the coastal wards was 0.0041 (0.42%), 95% CI: 0.31- 0.55 The median age of the 66 cases with ADD was 9 years, majority of the cases were below or equal to the age of 20 years. There was an almost equal distribution of gender. The majority of the cases had watery diarrhoea, followed by fever. About one-half of the cases used a public pipe water supply for drinking and washing utensils.There is significant statistical association between the practice of drinking unboiled water (p-value=0.036) and lack of hand hygiene practices (p-value=0.011) with the diarrhoeal cases.

Conclusion: The outbreaks of diarrhoeal diseases provide information to understand the factors associated with food and waterborne diseases and to identify ongoing and emerging threats. The practice of consuming unboiled water, lack of hand hygiene practices, water used for washing utensils and consuming food from places other than home were the significant transmission factors resulting in the current outbreak.

Keywords: Disease outbreaks, Food-borne illness, Sanitation, Public health surveillance

INTRODUCTION

Diarrhoeal disease is a leading cause of child mortality and morbidity globally and mostly results from contaminated food and water sources. It is the second leading cause of death in children under five years of age and is responsible for around 5 lakh deaths every year [1]. Worldwide estimates indicate that 780 million individuals lack access to improved drinking water and 2.5 billion lack improved sanitation [1]. It has been reported that in low-income countries, children under three years of age experience, on average, three episodes of diarrhoea every year [1]. Diarrhoeal diseases can lead to severe dehydration, fluid and electrolyte loss and predispose the child to malnutrition.

The ADD is a concern among children under five years of age in India, contributing to a large proportion of child morbidity and mortality [2]. The National Family Health Survey 2019-2021 shows that the prevalence of childhood diarrhoea is 7.3%, with a higher prevalence in rural areas [3]. It is the third most common cause of under-five mortality in the country. Outbreaks of water-borne diseases have been reported in the past years in the state of Kerala, which has remarkable social and health indicators and is already in the stage of epidemiological transition from communicable and infectious diseases to non communicable diseases [4]. Reports from the State Surveillance unit show around 4-5 lakh cases of ADD per year and an average of 4 deaths due to the disease in the years 2019 to 2024 in Kerala [5]. This stresses the importance of good sanitation, availability and access to clean water and hygienic practices in the community. The occurrence of an outbreak always signals some significant shift in the balance between the agent, host and the environment and calls for prompt action. A thorough investigation of the cases is needed to uncover the factors responsible and to guide in advocating control measures to prevent further spread, as well as to reduce morbidity and mortality.

Alappuzha district, which has the longest coastline in the state, is interspersed with numerous water bodies, has been plagued with the issue of drinking water shortage for many years and has been facing outbreaks of waterborne diseases every year. The first documented outbreak of diarrhoeal disease due to Norovirus was in Alappuzha municipality and nearby panchayats in 2021. The disease was reported among 950 persons, lasted for more than a month, and the source of infection was contaminated water [6]. Acute diarrhoeal diseases have been reported in the years that followed, with around 20,000 cases in the recent past few years [7]. In the year 2022, towards the end of November, according to the disease reporting in the Integrated Disease Surveillance Project

(IDSP) portal, the Alappuzha municipal area witnessed a steady rise in the number of ADD cases, with 11 cases on 28-11-2022 to an alarming 72 cases on 4-12-2022.

The present study aimed to understand the pattern of the diarrhoeal disease outbreak in this municipal area, to identify the causative agent and the epidemiological factors involved in the outbreak, so that measures can be adopted in the community. This outbreak investigation was intended to provide evidence to strengthen or modify the prevention and control measures in the area to prevent future outbreaks.

MATERIALS AND METHODS

This was an epidemiological investigation conducted as a cross-sectional analytical study done in December 2022 in the coastal wards, namely ward no. 41, 42 and 43 of Alappuzha Municipality, Alappuzha, Kerala, India, from where an increased number of ADD cases were reported in November 2022-December 2022. This study was conducted as an emergency response to the diarrhoea outbreak and was designed to provide information to orient the public health response with the objective to initiate and implement control measures; hence, ethical approval was not sought prior to the survey. Privacy, confidentiality and rights of patients were ensured during and after the conduct of the study. Oral informed consent was obtained from the participants of each household after a detailed explanation of the existence of an outbreak and the objective of the study. Institutional Ethics Committee approval was obtained (EC 60/2023) for the use of the data for dissemination and publication. The information was entered and analysed anonymously. The study was implemented in collaboration with the local administrative machinery, including the district health officials.

The total population of these coastal wards of Alappuzha municipality was 12,796, consisting of 6385 males, 6411 females and 766 under-five children. The study methodology involved primary data collection through a house-to-house survey to describe the outbreak and identify the factors associated with it.

- Case definition: A suspected case of ADD is a person residing in the coastal wards with a history of 3 or more episodes of loose watery stools in a day on or after 28 November 2022, with or without blood and mucous, along with presence of one or more symptoms like malaise/tiredness, abdominal pain, fever, nausea or vomiting [8,9].
- Control definition: Control was defined as a healthy person with no symptoms of ADD belonging to the same coastal wards and included either family members or persons in the neighbourhood, particularly from the areas where cases were identified.

Sample size calculation: The sample size was calculated taking the expected proportion of controls drinking inadequately boiled water as 40%, an anticipated Odds Ratio (OR) of 3, and case control allocation ratio of 1:2. The minimum sample size calculated with 95% confidence level and 90% power was estimated to be 46 cases in the study group and 92 controls in the comparison group [10]. The line list of persons with symptoms was obtained from the District Surveillance Unit (DSU), and selection of cases was done by consecutive sampling to include 66 persons with symptoms and 125 persons without symptoms in the comparison group.

Study Procedure

The investigation team conducted a house-to-house survey on 6th and 7th December 2022, by covering the households of the coastal wards and persons admitted in the hospitals using a specially designed case investigation form developed by the investigators.

The study variables included sociodemographic variables, clinical details like details regarding diarrhoea, date of onset, frequency of loose stools, presence of abdominal pain, fever, vomiting and nature of treatment undertaken, history of hospitalisation in any health facility due to diarrhoea, including current admission with duration. Details of food/drink intake, source of drinking water, food intake from outside before 5 days of onset of illness, details of household water purification, sanitary practices, hand hygiene and cultural practices, cleaning of utensils, type of latrine, type of sewage system; travel history 7 days before illness and number of family members with similar symptoms [ANNEXURE 1]. The water supply network of the entire area was enquired and information was collected regarding breaks in the pipelines in the past, as well as subsequent repairs and closures.

An investigator-administered questionnaire was used to collect information from the study participants. Water samples were taken from four points in the community for checking the Coliform count using the Most Probable Number (MPN) count method, stool samples and rectal swabs were taken for microbiological investigation and virological examination from patients admitted in hospitals and from persons with symptoms in the community on that day. Water samples were taken for testing the residual chlorine levels using a Chloroscope. (Model-A; Batch Number S0906).

STATISTICAL ANALYSIS

Data was entered in Microsoft Excel and analysed using Statistical Package for Social Sciences (SPSS) version 27.0 (Inc., Chicago, USA). Descriptive statistics (frequency & percentage) were used to present the sociodemographic characteristics and prevalent symptoms among cases. Quantitative variables were expressed as mean with SD or median with Q1, Q3. The association of the possible factors were tested using the Chi-square test, and a p-value of less than 0.05 was considered statistically significant.

RESULTS

An epidemiological investigation was carried out with the help of field workers, who searched actively for cases in all three coastal wards and collected data from 191 persons using the questionnaire. Out of them, 66 persons gave a history of recent onset of loose stools with or without blood and/ mucous, plus presence of one or more symptoms: malaise/tiredness, abdominal pain, fever, nausea or vomiting. The prevalence of ADD among children in the under-five age group in the coastal wards was 0.020 (2.1%) 95% CI: 1.2- 3.4 and in the age group above five years (5 -64 years) in the coastal wards was 0.0041 (0.42%) 95% CI: 0.31- 0.55 [Table/Fig-1].

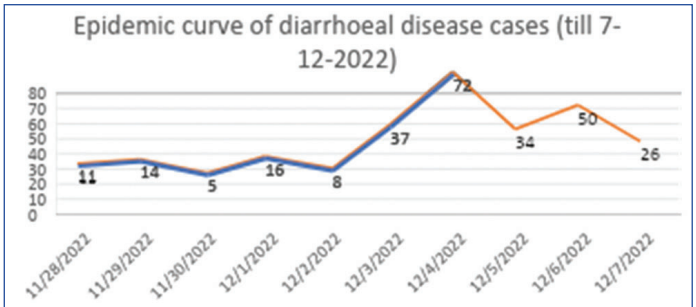
Demographic characteristics	Number of cases	Population in the wards	Prevalence
Age			
≤5 years	16	766	2.1%
>5 years	50	12030	0.42%
Gender			
Male	32	6385	0.5%
Female	34	6411	0.53%

[Table/Fig-1]: Prevalence of ADD in the coastal wards by age and gender.

The increase in the number of cases presenting to the hospital was noted from 28th November onwards, with a peak in the cases on 4th December and then cases were gradually decreasing [Table/Fig-2]. Active and passive surveillance of diarrhoea cases was continued for the next two weeks with the help of field staff, Accredited Social Health Activist (ASHAs) and community volunteers, till no new cases were reported.

Demographic Profile

The median (Q1, Q3) age of the cases was 9 years (5,17.25) and ranged from 6 months to 64 years. Majority of the cases, 52 (78.8 %) were equal to or below the age of 20 years. There was an almost equal distribution of gender, with 32 (48.5%) being males and 34 (51.5%) being females [Table/Fig-3].

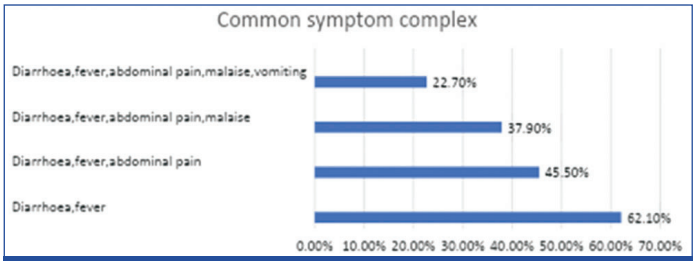


[Table/Fig-2]: Time distribution of diarrhoeal disease cases reported to the hospitals from the area.

Characteristics	Study population n (%)
Age group	
0-5 years	16 (24.2)
6-10 years	17 (25.8)
11-20 years	19 (28.8)
21-40 years	10 (15.2)
41-60 years	3 (4.5)
Above 60 years	1 (1.5)
Gender	
Male	32 (48.5)
Female	34 (51.5)
Clinical characteristics	
Fever	47 (71.2)
Vomiting	41 (62.1)
Watery diarrhoea	53 (80.3)
Mucous in stool	15 (22.7)
Blood in stool	6 (9.1)
Nausea	20 (30.3)
Abdominal pain	47 (71.2)
Malaise	42 (63.6)
Muscle pain	15 (22.7)
Severity of symptoms	
Took OP consultation	49 (74.2)
Hospitalised	17 (25.8)

[Table/Fig-3]: Demographic and clinical profile of the ADD cases (n=66).
OP: Outpatient

The majority of the cases had watery diarrhoea 53 (80.3%), followed by fever 47 (71.2%) and abdominal pain 47 (71.2%) [Table/Fig-3]. Among the combination of symptoms, diarrhoea and fever were the most common reported by 41 (62.1%) [Table/Fig-4].



[Table/Fig-4]: Clinical characteristics of the ADD cases (n=66).

The majority, 34 (51.5%) of the cases used a pipe water supply (public), followed by a Reverse Osmosis (RO) water plant, 24 (36.4%) for drinking [Table/Fig-5]. Out of the 34 persons who used a public water connection for drinking, only 31 persons had the habit of boiling the water and out of them, only 25 persons boil the water for more than 10 minutes. Out of the 25 persons who boil the water for more than 10 minutes, 7 had the habit of mixing unboiled water with the boiled water to make it drinkable. So, among the cases using public pipe water, only 18 (53%) were consuming drinking water after proper boiling practices like roll boiling for 10-20 minutes. Among the 24 cases using RO water, only 5 persons were in the habit of boiling the RO water for drinking and out of them, 4 persons out of the 5 added unboiled water to the boiled RO water.

Majority 42 (63.6%) used public pipe water, followed by bore well 14 (21.2%) and well water 9 (13.6%), for cleaning utensils. Among the cases, 40 (60.6%) regularly washed their hands before food, and 57 (86.4%) regularly practised hand hygiene measures after using the toilet. Around 47 (71.2%) of the cases had a water seal type of latrine in their homes, and 63 (95.5%) of them had a septic tank in their homes [Table/Fig-5].

Characteristics	n (%)
Source of drinking water	
Pipe water supply (public)	34 (51.5)
RO water plant	24 (36.4)
Mineral water	5 (7.6)
Rainwater	1 (1.5)
Well water	1 (1.5)
Pipe water and RO water	1 (1.5)
Food	
Food intake from outside home	12 (18.2)
Water source for cleaning utensils	
Public pipe water	42 (63.6)
Bore well	14 (21.2)
Well water	9 (13.6)
Pond/canal water	1 (1.5)
Hand washing	
Before having food	40 (60.6)
After using toilet	57 (86.4)
Sanitation	
Water seal type of latrine	47 (71.2)
Septic tank sewerage system	63 (95.5)

[Table/Fig-5]: Epidemiological characteristics of the cases (n=66).

Factors associated with the outbreak

The 66 persons with symptoms were included as cases and the 125 persons without symptoms were included as controls [Table/Fig-6]. The total controls (125) included 80 persons from the same household without symptoms as household controls and 45 persons without symptoms in the neighbouring houses as neighbourhood controls.

Characteristics	Cases (n=66)	Controls (n=125)
Age (mean±SD)	13.16±10.46 years	28.37±14.49 years
Gender		
Male	34 (51.5%)	48 (38.4%)
Female	32 (48.5%)	77 (61.6%)
Source of drinking water		
Public pipe supply	34 (51.5%)	69 (55.2%)
RO water	24 (36.4%)	46 (36.8%)
Mineral water	5 (7.6%)	10 (8%)
Rain water	1 (1.5%)	-
Well water	1 (1.5%)	-
Practice of boiling water		
Yes	42 (63.6%)	96 (76.8%)
No	24 (36.4%)	29 (23.2%)
Practice of roll boiling water		
Yes	37 (56.1%)	89 (71.2%)
No	29 (43.9%)	36 (28.8%)

Hand hygiene practices		
Yes	41 (62.1%)	99 (79.2%)
No	25 (37.9%)	26 (20.8%)
Water used for cleaning utensils		
Public pipe water	42 (63.6%)	75 (60%)
Bore well water	14 (21.2%)	28 (22.4%)
Well water	9 (13.6%)	22 (17.6%)
Pond/canal water	1 (1.5%)	-

[Table/Fig-6]: Demographic and epidemiological characteristics of the cases (n=66) and controls (n=125).

Analysis done with cases (n=66) compared with controls (n=125) showed a statistically significant association between the diarrhoeal cases and similar illness in other family members. {p-value <0.001, Odds Ratio (OR)-9.145,95% Confidence Interval (CI):4.531- 18.457}, which indicated household transmission of infection. There is a significant statistical association between the practice of drinking unboiled water (p-value=0.036) and lack of hand hygiene practices (p-value=0.011) with the diarrhoeal cases. The household practice of boiling water for drinking (OR-0.516, 95%CI:0.277-0.961) and the proper hand hygiene practices before food (OR-0.431, 95% CI:0.223-0.832) were statistically significant protective factors [Table/Fig-7].

S. No.	Character-istics	Categories	Case (66) n (%)	Control (125) n (%)	χ^2 statistic	p-value	Crude OR (95% CI)
1	Similar symptoms in other family members	Yes	40 (60.6)	18 (14.4)	43.612	<0.001	9.145 (4.531-18.457)
		No	26 (39.4)	107 (85.6)			
2	Drinking boiled water	Yes	37 (56.1)	89 (71.2)	4.410	0.036	0.516 (0.277-0.961)
		No	29 (43.9)	36 (28.8)			
3	Hand washing practices	Yes	41 (62.1)	99 (79.2)	6.437	0.011	0.431 (0.223-0.832)
		No	25 (37.9)	26 (20.9)			
4	Food from outside	Yes	12 (18.2)	11 (8.8)	3.589	0.058	2.303 (0.955-5.552)
		No	54 (81.8)	114 (91.2)			

[Table/Fig-7]: Factors associated with the diarrhoeal disease outbreak.

The controls included 80 persons without symptoms from the same household as household controls and univariate analysis done with cases compared with household controls also showed significant statistical association between hand hygiene practices and diarrhoeal cases (p-value=0.017). Practising hand hygiene measures before food and after using toilet was found to be protective against diarrhoeal disease (OR- 0.410, 95% CI:0.196- 0.859) [Table/Fig-8].

S. No.	Character-istics	Categories	Cases (n=66) n (%)	Household controls (n=80) n (%)	χ^2 statistic	p-value	Crude OR (95% CI)
1	Hand washing practices	Yes	41 (62.1)	64 (80)	5.724	0.017	0.410 (0.196-0.859)
		No	25 (37.9)	16 (20)			
2	Drinking boiled water	Yes	37 (56.1)	52 (65)	1.214	0.270	0.687 (0.352-1.341)
		No	29 (43.9)	28 (35)			
3	Consuming food from outside	Yes	12 (18.2)	10 (12.5)	0.912	0.340	1.556 (0.625-3.869)
		No	54 (81.8)	70 (87.5)			

[Table/Fig-8]: Factors associated with the diarrhoeal disease outbreak, comparison with household controls.

The controls included 45 persons without symptoms from the neighbouring houses, and analysis was done with cases compared with neighbourhood controls to understand the broader environmental and community-level factors associated with the outbreak. A significant statistical association was found between diarrhoeal cases and drinking unboiled water and consuming food from eateries outside the home. Consuming food from outside eateries within 3-days of the symptoms was found to be associated with diarrhoeal cases. (p-value=0.010, OR-9.778 (95% 1.223-78.146), and the habit of drinking boiled water was protective against diarrhoeal cases (p-value=0.004, OR-0.276, 95%CI:0.112- 0.682) [Table/Fig-9].

S. No.	Character-istics	Categories	Case (n=66) n (%)	Neigh-bourhood control (n=45) n (%)	χ^2 sta-tistic	p-value	Crude OR (95% CI)
1	Consuming food from outside	Yes	12 (8.2)	1 (2.2)	6.591	0.010	9.778 (1.223-78.146)
		No	54 (81.8)	44 (97.8)			
2	Drinking boiled water	Yes	37 (56.1)	37 (82.2)	8.241	0.004	0.276 (0.112-0.682)
		No	29 (43.9)	8 (17.8)			

[Table/Fig-9]: Factors associated with the diarrhoeal disease outbreak, comparison with neighbourhood controls.

As approximately 79% of the cases were less than 20 years of age, for analysis, the cases and controls were stratified into two groups: less than or equal to 20 years and more than 20 years. In the age group less than 20 years, drinking boiled water was found to be a statistically significant protective factor against diarrhoeal disease. (p-value=0.023, OR-0.333, 95%CI 0.127-0.877) [Table/Fig-10].

S. No.	Character-istics	Categories	Cases (n=52) n (%)	Controls (n=32) n (%)	χ^2 statistic	p-value	Crude OR (95% CI)
1	Drinking boiled water	Yes	26 (50)	24 (75)	5.139	0.023	0.333 (0.127-0.877)
		No	26 (50)	8 (25)			
2	Consuming food from outside	Yes	9 (17.3)	4 (12.5)	0.350	0.554	1.465 (0.411-5.219)
		No	43 (82.7)	28 (87.5)			
3	Drinking water source	Public pipe supply	25 (48.1)	21 (65.6)	2.462	0.117	0.485 (0.195-1.205)
		Other sources	27 (51.9)	11 (34.4)			

[Table/Fig-10]: Factors associated with the diarrhoeal disease outbreak in the age group less than 20 years.

In the age group above 20 yrs, a significant statistical association was found between washing utensils with water from the public pipe supply and the diarrhoeal cases (p-value=0.034, OR-4.731, 95%CI:1.002-22.331) [Table/Fig-11].

The water used for washing utensils (p-value=0.008,OR- 7.714, 95% CI: 1.479-40.243) and consuming food from outside (p-value=0.043, OR- 1.302, 95%CI: 1.128-1.504) were also found to be significant risk factors in the age group above 20 years, when compared with neighbourhood controls [Table/Fig-12].

Laboratory Analysis

A total of 14 stool samples and 4 rectal swabs collected during the outbreak from the cases having diarrhoea were sent for culture, bacteriological and virological tests to the Microbiology laboratory and the Research laboratory in Alappuzha. Two stool samples taken from cases showed the presence of Norovirus, while the other samples did not show any positive results on virological examination. None of the stool samples showed growth of organisms in bacteriological

S. No.	Character-istics	Categories	Caess (n=14) n (%)	Controls (n=93) n (%)	χ^2 sta-tistic	p-value	Crude OR (95% CI)
1	Washing utensils with pipe water	Yes	12 (85.7)	52 (55.9)	4.496	0.034	4.731 (1.002-22.331)
		No	2 (14.3)	41 (44.1)			
2	Consuming food from outside	Yes	3 (21.4)	7 (7.5)	2.776	0.096	3.351 (0.754-14.882)
		No	11 (78.6)	86 (92.5)			
3	Drinking boiled water	Yes	11 (78.6)	65 (69.9)	0.445	0.505	1.579 (0.409-6.101)
		No	3 (21.4)	28 (30.1)			

[Table/Fig-11]: Factors associated with the diarrhoeal disease outbreak in the age group more than 20 years.

S. No.	Character-istics	Categories	Cases (n=14) n (%)	Controls (n=32) n (%)	χ^2 statistic	p-value	Crude OR (95% CI)
1	Consuming food from outside	Yes	3 (21.4)	1 (3.1)	4.110	0.043	1.302 (1.128-1.504)
		No	11 (78.6)	31 (96.9)			
2	Washing utensils with pipe water	Yes	12 (85.7)	14 (43.8)	6.979	0.008	7.714 (1.479-40.243)
		No	2 (14.3)	18 (56.3)			

[Table/Fig-12]: Factors associated with the diarrhoeal disease outbreak in the age group more than 20 years, comparison with neighbourhood controls.

analysis. Four water samples were collected from the community and tested at the Microbiology laboratory, of which two water samples showed coliforms and had a high level of contamination. Even though it was said that super-chlorination was done recently, the residual chlorine in the wells in the area was found to be less than 1 ppm.

DISCUSSION

Diarrhoeal diseases are a constant presence in most communities; the events are underreported or unrecognised unless it become a cause of concern. The current outbreak occurred in a coastal area with a peak of 72 cases reported on a single day. The increase in cases was observed in the daily reporting of diarrhoeal disease cases through the IDSP platform. The major symptom in the outbreak, apart from diarrhoeal episodes, was fever, which was reported in around 60% of the cases. Soorya V et al., in their study analysed the data of water-borne diseases in districts of Kerala and described the pattern and seasonal trends in these diseases [11]. This retrospective descriptive multi-year analytical study used communicable disease data from the Directorate of Health Services (DHS) Kerala portal during 2011 to 2019. The study showed that among communicable diseases, water-borne diseases accounted for the highest proportion at 97%, with diarrhoea (ADD) being the most commonly reported water-borne disease in Kerala.

It has also been reported that there is an increasing trend in water-borne diseases after 2018. The cases of Hepatitis A, Cholera and Typhoid have reduced in these years, whereas ADD cases have increased over the years [11].

The age groups 0 to 5 years and 6 to 10 years had the maximum number of cases in this study, with 78.8% of cases being reported in the age group below 20 years. A community-based cross-sectional survey carried out in two panchayats of Thiruvanathapuram showed that the prevalence of diarrhoeal diseases in the high-risk group of under-five-year-old children in the 2 weeks preceding the survey was 8.7%, of which 25.3% of the cases were under 2 years of age [12].

An outbreak investigation by Sheoran P et al., in Nagpur, found that the outbreak of ADD was due to contaminated drinking water from alternate sources during a break in the regular water supply [13]. A similar outbreak investigation of Cholera by Goswami S et al., used pretested, predesigned epidemiological case sheets obtained from IDSP. Line listing, collection of stool and water samples, immediate referral, and treatment of the patients were done. The study showed the importance of using a sensitive case definition and timely detection through surveillance [14]. The line listing of cases in this study was also done through the surveillance network of IDSP.

One of the factors associated with the present outbreak was the practice of inadequately boiled water for drinking, which was seen in 43.9% of the cases as compared to 28.8% of the controls. (p-value=0.036) The practice of roll boiling the water for 10 to 20 minutes and the practice of mixing boiled water with unboiled water were required to assess the practice of boiling drinking water. The practice of boiling water adequately was protective against diarrhoeal diseases (OR-0.516, 95%CI:0.277-0.961). Inadequately boiled water from the municipal water supply was also associated with a Norovirus diarrhoeal outbreak in 2021 in Alappuzha, in a study by Rajeevan A et al., [10]. Consumption of unboiled water has been consistently identified as a major risk factor in diarrhoeal disease outbreaks.

Hand hygiene practices are a preventive health behaviour that can go a long way in preventing communicable diseases. Practising hand washing with soap and water was found to be protective in this study (OR-0.431, 95% CI: 0.223- 0.832). Hand washing is a highly effective and essential intervention for preventing diarrhoea, especially among children under five years of age [15]. Community-based trials in low- and middle-income settings demonstrated a reduction in the incidence of diarrhoea by approximately one-third following hand washing promotion [16,17]. Several studies have shown that hand hygiene is one of the most cost-effective interventions for diarrhoea prevention. A study on diarrhoeal disease outbreak in a tribal village in South India showed that good hand hygiene practices are protective against diarrhoeal diseases (OR-0.4, 95% CI 0.2-0.7) [18]. Similar results have been shown in other studies where hand hygiene has reduced the odds of diarrhoeal disease in children [19]. Not practising hand hygiene was significantly associated with diarrhoeal disease outbreak in a study done in Assam [20].

A study on the outbreak of ADD by Anandan M et al., showed that contaminated water supplied from the borewell could be the potential exposure for the ADD outbreak in Thiruper village [21]. The attack rate of ADD was higher among the cases who consumed water supplied through the leaked pipelines than the controls (OR=3.7; 95% CI=1.1 to 16.4). The investigation suggested that the outbreak might have occurred due to the consumption of faecal contaminated water supplied through damaged pipelines floods post-cyclone [21]. In the present study, more than half of the study population used pipe water supply for drinking (51.5%) and for household purposes (63.6%), and 21.2% used bore well water for cleaning utensils. In a study in a tribal village, the ADD outbreak was associated with the drinking water source being the bore well water [18].

Household transmission plays a critical role in amplifying diarrhoeal outbreaks, particularly in high-density living conditions with shared water and sanitation facilities. In the present study, 60.6% of the cases gave a history of similar illness in family members as compared with 14.4% of controls, and this was found to be statistically significant (p-value <0.001). Norovirus is highly transmissible, with the transmission being foodborne, waterborne, direct person-to-person, or through fomites. Having similar illnesses in roommates and in the same family has been significantly associated with previous reports of Norovirus outbreaks [10].

Consumption of food from restaurants and eateries has been frequently implicated in ADD outbreaks in India, often acting as a point source of infection affecting large numbers within a short period. In the present study, consumption of food from eateries outside the

home was found to be associated with the ADD cases (OR-9.778, 95%CI:1.223-78.146). Similar results have been observed in other studies, where consumption of food from restaurants 4-days before the onset of illness was found to be associated with diarrhoeal disease [10].

Outbreak data have been used in the past to inform the development and implementation of drinking water regulations worldwide [22]. The immediate remedial action was taken by the research team at the local level, like health education regarding safe drinking water and proper household water storage practices, use of chlorine tablets and medications, water disinfection by boiling, proper hand washing before and after defecation and home available fluids or ORS in case of dehydration and proper sanitation measures. Further spread of the disease was controlled by active detection of diarrhoea cases by house-to-house survey by the rapid response team, prompt treatment of the cases, distribution of ORS packets and zinc tablets, water sampling of the other water sources and super chlorination of the wells.

In the present study, it was found that there was a break in the public water supply for 3-days, the week before symptoms started. Pipelines with multiple breakages and leakages are a common phenomenon in India [23]. In addition, in many parts of India where there is a piped water supply system, water pipes and sewage channels are laid beside each other, possibly for engineering convenience [24]. Thus, mixing of sewage with water could potentially occur at multiple points [25]. In places where the water supply is intermittent, thereby increases the risk of contamination owing to the negative suction pressure during the supply intervals. With rainfall, submergence of supply pipes in a contaminated environment increases the likelihood of contaminated water entering the water pipe. Unsafe water is a critical factor in the spread of diarrhoeal diseases and outbreaks [26]. Addressing water quality, sanitation, and hygiene is essential to prevent and control these outbreaks, especially in vulnerable populations and resource-limited settings [27].

Health education was carried out in each household regarding transmission of diarrhoeal disease and its prevention. The health education was primarily directed towards hand hygiene, chlorination, and cleanliness practices within households during outbreaks through trained medical teams. Health education materials regarding prevention of diarrhoeal diseases and preparation of bleach solution for household use and sanitation purposes were distributed in the affected houses and their neighbourhood.

Outbreak investigations are important learning opportunities for recognising threats to safe water, uncovering contributing factors to water and food contamination, and identifying ways to prevent future outbreaks. Morbidity due to water-borne diseases is mainly due to ADD, which can be reduced through effective grassroots-level coordination [28].

The present study recommends the short term measures like (i) ensure proper roll boiling (minimum 10-20 minutes) of drinking water before consumption, (ii) proper hand hygiene practices to be followed before consuming food as well as after using toilets, (iii) washing of utensils with clean water to be ensured, (iv) cooked food items have to be consumed hot, (v)irrespective of water source all water should be adequately boiled before consumption, (vi) avoid mixing of unboiled water to boiled water, (vii) ensure and monitor proper chlorination at consumer level, (viii) emphasise on utilisation of bleach solution for cleaning of surfaces constantly touched by patients during outbreaks (1%), toilets (5%), (ix) avoid touching of eyes, mouth and nose with unwashed hands. Long-term recommendations include ensuring a wholesome water supply to the entire area, strengthening School health programs with emphasis on ensuring availability of proper drinking water and hand hygiene practices, and an in-depth exploration of the public water source and pipeline system is mandated with the help of the public works department.

Limitation(s)

This investigation had certain limitations. Mild or self-limiting cases of acute diarrhoeal disease may not have sought medical attention and thus remained unreported, leading to underestimation of the true magnitude of the outbreak. Recall bias is possible, as exposure histories were obtained retrospectively, and participants may have inaccurately reported water or food sources. Environmental and water samples were collected after the onset of control measures, which could have reduced the likelihood of detecting the causative pathogen. Limited laboratory capacity restricted testing for certain viral agents. The study could not investigate the contribution of person-to-person or fomite-borne transmission.

CONCLUSION(S)

Evidence from the case distribution, including prevalence, epidemic curve, clinico-epidemiological observations and environmental survey, points to the possibility of the occurrence of an acute diarrhoeal disease outbreak at Alappuzha Municipality, transmitted through contaminated water. The practice of consuming unboiled water from public pipeline and RO plant, lack of hand hygiene practices, washing utensils using contaminated water and consuming food from restaurants and eateries other than home were the significant transmission factors resulting in the current outbreak. Proper reporting of diseases from the field through a robust surveillance system and follow-up activities plays an important role in curbing the spread of diseases in the community. Compiling and sharing outbreak reports supports public health efforts to protect the public from food and water-borne diseases.

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REFERENCES

[1] World Health Organization. Diarrhoeal disease [Internet]. Geneva: WHO; [cited 2023 Feb 13]. Available from: https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease.
[2] Manetu WM, M'masi S, Recha CW. Diarrhea Disease among Children under 5 Years of Age: A Global Systematic Review. Open Journal of Epidemiology. 2021;11:207-21.
[3] Ministry of Health and Family Welfare (India). National Family Health Survey (NFHS-5), 2019-21: India report [Internet]. New Delhi: MoHFW; [cited 2023 Feb 16]. Available from: https://main.mohfw.gov.in/sites/default/files/NFHS-5_Phase-II_0.pdf.
[4] Yadav S, Arokiasamy P. Understanding epidemiological transition in India. Glob Health Action. 2014;7:10.3402/gha.v7.23248.
[5] Directorate of Health Services, Kerala. Weekly morbidity report, 29 February 2020 [Internet]. Thiruvananthapuram: DHS Kerala; [cited 2023 Feb 13]. Available from: https://dhs.kerala.gov.in/wp-content/uploads/2020/03/data_29022020.pdf.
[6] Outlook India. Norovirus cases: Centre asks Kerala State Surveillance Office to submit report [Internet]. New Delhi: Outlook India; 2022 Jun 6 [cited 2023 Feb 13]. Available from: https://www.outlookindia.com/national/norovirus-cases-centre-asks-kerala-state-surveillance-office-to-submit-report-news-200669.
[7] Directorate of Health Services, Kerala. Kerala - Communicable Disease Data for 2022 [Internet]. Thiruvananthapuram: State Surveillance Unit, Directorate of Health Services; 2023 Jul 8 [cited 2023 Feb 13]. Available from: https://dhs.kerala.gov.in/.
[8] Outbreak Tools. Case definitions - Outbreak Toolkit [Internet]. [place unknown]: Outbreak Tools; [cited 2025 Aug 15]. Available from: https://outbreaktools.ca/background/case-definitions.
[9] World Health Organization, Regional Office for the Eastern Mediterranean. Disease outbreaks [Internet]. Cairo: WHO EMRO; [cited 2023 Feb 14]. Available from: http://www.emro.who.int/health-topics/disease-outbreaks/index.html.
[10] Rajeevan A, Sakthivel M, Menon N, Sachin KC, Sudersanan H, Nagarajan R, et al Norovirus outbreaks due to contaminated drinking water and probable person-to-person transmission, Kerala, India, 2021. J Infect Public Health. 2024;17:102568. Doi: 10.1016/j.jiph.2023.12.007
[11] Soorya V, Raj J, Anitha Kumar KR. Trends in water borne diseases in Kerala: An analysis of directorate of health services portal data. International Journal of Research in Medical Sciences. 2021;9(8):2381-88.
[12] Chitraa GA , Nair VM Prevalence of Diarrhoeal Diseases – An Indicator for Poor Environmental Sanitation Kerala Medical Journal | January-March 2010 | Vol III Issue 1.

[13] Sheoran P, Rammayyan A, Shukla HK, Dikid T, Yadav R, Sodha SV. An outbreak investigation of acute Diarrheal Disease, Nagpur District, Maharashtra, India. Indian Journal of Public Health. 2021;65:14.
[14] Goswami S, Jha A, Sivan SP, Dambhare D, Gupta SS. Outbreak investigation of cholera outbreak in a slum area of urban Wardha, India: An interventional epidemiological study. J Family Med Prim Care. 2019;8:1112-16.
[15] Ejemot-Nwadiaro RI, Ehiri JE, Arikpo D, Meremikwu MM, Critchley JA. Hand-washing promotion for preventing diarrhoea. Cochrane Database Syst Rev. 2021;2021:CD004265.
[16] World Health Organization. Hand washing promotion for preventing diarrhoea [Internet]. Geneva: WHO; [cited 2025 Jul 14]. Available from: https://www.who.int/tools/elena/review-summaries/wsh-diarrhoea--hand-washing-promotion-for-preventing-diarrhoea.
[17] Shah HD, Desai B, Jadav P, Shah N, Kadikar R, Singh AJ. An epidemiological investigation of a cholera outbreak in peri-urban slum settlements of Gujarat, India. Journal of Family Medicine and Primary Care. 2022;11:6061.
[18] Maramraj KK, Subbalakshmi G, Ali MS, Dikid T, Yadav R, Sodha SV, et al. A community-wide acute diarrheal disease outbreak associated with drinking contaminated water from shallow bore-wells in a tribal village, India, 2017. BMC Public Health. 2020;20:231.
[19] Khan KM, Chakraborty R, Brown S, Sultana R, Colon A, Toor D, et al. Association between Handwashing Behavior and Infectious Diseases among Low-Income Community Children in Urban New Delhi, India: A Cross-Sectional Study. Int J Environ Res Public Health. 2021;18:12535.
[20] Hariprasad R, Baruah PJ, Kumar MS, Sarmah P, Mahanta TG, Bhatnagar T. Investigation of an outbreak of acute diarrheal disease in Dibrugarh district, Assam, India, 2023. Clin Epidemiol Glob Health. 2024;29:101767. Doi: 10.1016/j.cegh.2023.101767.
[21] Anandan M, Vs S, Rubeshkumar P, Ponnaiah M, Jesudoss P, Karumanagounder K, et al. Outbreak of acute diarrhoeal disease attributed to consumption of faecal contaminated water supplied through damaged pipelines in Thiruper, Tiruvallur district, Tamil Nadu, India, 2016. Clinical Epidemiology and Global Health. 2021;10:100701.
[22] Centers for Disease Control and Prevention. Prevent future outbreaks through summarizing, interpreting, and reporting findings: Waterborne disease outbreak investigation toolkit [Internet]. Atlanta (GA): CDC; 2022 [cited 2023 Feb 16]. Available from: https://www.cdc.gov/healthywater/emergency/waterborne-disease-outbreak-investigation-toolkit/prevent-outbreaks.html.
[23] Mudur G. India's burden of waterborne diseases is underestimated. BMJ. 2003;326:1284. Doi: 10.1136/bmj.326.7398.1284 .
[24] Kapse G, Agnihotri S, Sekhsaria P, Sastry M. Analysing the interlinkage between diarrhoea and drinking water faecal contamination in India. J Water Health. 2024;22:1111-24. Doi: 10.2166/wh.2024.164.
[25] Sarkar R, Prabhakar AT, Manickam S, Selvapandian D, Raghava MV, Kang G, et al. Epidemiological investigation of an outbreak of acute diarrhoeal disease using geographic information systems. Transactions of the Royal Society of Tropical Medicine and Hygiene. 2007;101:587-93.
[26] Khan AI, Islam MdT, Amin MA, Khan ZH, Qadri F. Outbreak of diarrheal diseases causes mortality in different geographical locations of Bangladesh during the 2021 COVID-19 era. Front Public Health. 2023;11:1103518.
[27] Kerketta S, Rout UK, Kshatri JS, Kerketta AS, Paikaray AK, Dash A, et al. An acute diarrheal disease outbreak in urban setting of Odisha, India. BMC Infect Dis. 2025;25:283.
[28] Bashar MA, Soundappan K. Outbreak investigation of acute watery diarrhea in a village of North India: Timely action saved lives. The Journal of Infection in Developing Countries. 2022;16:843-49.

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ANNEXURE 1

QUESTIONNAIRE

Name :

Form number:

Age:

Gender:

Occupation:

Address:

Contact phone number:

If child under 18, Name & occupation of father/ mother:

Details of signs and symptoms

Date and time of onset of illness:

Symptoms*

- acute watery diarrhoea
- nausea
- vomiting
- abdominal pain
- fever
- tiredness/malaise
- acute bloody diarrhoea
- acute mucous diarrhoea
- headache
- chills
- muscle ache
- Other _____

Specify duration of symptoms selected in days, eg. a. 2-days, b.1-day, etc*:

How many times per day if selected 'diarrhoea':

How many times per day if selected 'vomiting':

Any other person share similar symptoms?:

H/o food intake in the last 3 days before illness (with date) :

Suspected food or drink- details, location,

H/o food/drink intake at any common gathering/ event? If so, details:

Any common food source/place of buying? If so, details:

Source of drinking water

- pipe water supply (public)
- well
- RO water plant
- Other _____

Any common water source, if so, what/ where?:

	Yes	No	Maybe
Is the water boiled before drinking?			
if yes, do you boil for > 10 minutes			
do you mix boiled water with unboiled water			
do you use water filter?			

Hand hygiene measures are practised just before eating/handling food

- soap and water
- sanitizer
- other_____

Utensils cleaned using

- public pipe water
- well water
- pond/canal water
- Other _____

If yes to the above question, specify the place, date, what food, and how many times

H/o food intake from outside/neighbouring house before 5 days of onset of illness, if so, details

Wash your hands with soap after using the toilet

- Yes
- No
- Sometimes

Household or contact with similar symptoms?

How many members in in-house?

How many members with similar symptoms? if so, any under 5 years?

Type of latrine

- water seal
- digging hole
- other

H/o travel 7 days before illness? If so, where, when?

	Yes	No	Maybe
Has received treatment			
Hospitalisation			
ICU admission			

Type of sewage system

- Septic tank
- Soakage pit
- Other_____

Treatment details- place, treatment received

Recovered?

Stool sample taken/not

Any other relevant detail: