Original Article

Outbreak investigation of acute watery diarrhea in a village of North India: timely action saved lives

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Abstract
Introduction: Outbreaks of acute watery diarrhoea are common in developing countries having poor access to safe drinking water and sanitation. An outbreak of acute watery diarrhoea in a village in North India was investigated with the aim to initiate and recommend necessary actions to control it.
Methodology: A house to house survey using a specially designed case record form was conducted covering all the households. Stool samples of some of the affected individuals and twenty water samples during and after the outbreak from various sites were collected for laboratory analysis.
Results: Out of 624 inhabitants surveyed, 118 were found to be suffering from acute watery diarrhoea (Overall attack rate of 18.9%) with two suspected deaths following diarrhoea. Males and females were affected equally and the age group of 15–44 years was affected predominantly. A peculiar epidemic curve with single peak was noted. One of the stool samples collected during the outbreak grew *Vibrio Cholera* O1(Ogawa) and twelve out of the twenty water samples including the samples from both the tube wells had high coliform counts indicating fecal contamination. Chlorine levels in all the water samples were found to be inadequate.
Conclusions: Local cultural practices such as indiscriminate defecation in public places, using tullu pumps to extract water from the public supply line, poor engineering design and maintenance of the water supply system having leakages at many sites along with inadequate chlorination of the supply water from the tube wells were the risk factors that could have contributed to this outbreak.

Introduction

As per World Health Organization, diarrhoea is defined as the passage of three or more loose or liquid stools per day (or more frequent passage than is normal for the individual) [1]. Diarrhoeal diseases represent a major health problem in developing countries. Conservative estimates place the global death toll from diarrhoeal diseases, between 1992 and 2000, at about two million deaths per year (1.7-2.5 million deaths), ranking third among all cases of infectious disease deaths worldwide [2]. However, in 2016, global toll from diarrhoeal diseases was a total of 1,655,944 deaths (95% uncertainty interval [UI], 1,244,073-2,366,552) as estimated by The Global Burden of Diseases, Injuries, and Risk Factors Study, signifying only a marginal reduction over the years [3]. The leading risk factors for diarrhoea identified were childhood wasting (low weight for height score) and unsafe water, and poor sanitation [3].

The aetiology of diarrhoea is very diverse, important aetiological enteropathogens are *Vibrio Cholerae, Escherichia coli, Salmonella* spp., *Shigella* spp. [4]. Most of the pathogenic organisms that cause diarrhoea are transmitted primarily or exclusively by the faeco-oral route. Faeco-oral transmission may be water-borne; food-borne, or direct transmission, which implies an array of other faeco-oral routes such as via fingers, or fomites, or dirt mostly ingested by the young children [5]. A significant proportion of diarrhoeal disease can be prevented through provision of safe drinking water and adequate sanitation and hygiene measures.

An outbreak or epidemic is defined as "the unusual occurrence in a community or region of disease, specific health-related behaviour or other health related events clearly in excess of "expected occurrence" [6]. The prime purpose of an outbreak investigation is to control the outbreak, limit its spread to other areas and assess how preventive strategies could be further

strengthened to reduce or eliminate the risk of such outbreak in future [7].

Contaminated drinking water continues to be the source for most diarrhoeal outbreaks recorded in India [8-21]. Quick actions taken with simple and rapid field epidemiological and laboratory investigations together can curb such an outbreak before it progresses into an epidemic/larger outbreak leading to higher morbidity/mortality.

On 20 July, 2018, a large number of cases of diarrhoea and a suspected death due to diarrhea from a village in Mullana block of Ambala district, Haryana, North India there was reported through a leading local newspaper. The local health team consisting of Medical Officer of the concerned Primary Health Centre (PHC), Nurses and Auxiliary Nurse Midwives had immediately started to treat the cases and the District surveillance officer activated the diarrhoeal surveillance. The mainly affected area was a single village having a population of approximately 1,300. As the affected village was near to the field practice area of Rural Health Training Centre (RHTC), Naraingarh under the Department of Community Medicine, Post graduate Institute of Medical education and Research (PGIMER), Chandigarh, a rapid response team (RRT) was constituted after taking appropriate permissions from district health authorities and investigation of the situation was started. On 21 July, 2018, the RRT visited the affected village and surveyed the area. The RRT consisted of one Senior Resident doctor, one Public Health Nurse and two health workers under guidance of a faculty member.

Methodology

The study methodology consisted of generating primary data through house to house survey to describe the outbreak in terms of time, place and person.

Study area

The affected Nakhrauli village (12.813964 N, 79.132305 E) in Mullana community development block of district Ambala in state of Haryana, North India, is a small village with a total population of 1,341. The adult literacy rate of the village is 67.0% (Census 2011). The village has two Aanganwadi centers and one Panchayat Bhawan and is served by a Primary Health Centre (PHC) located at a distance of 10 Km from the village. The drinking water supply in the village is through two tube wells located at the two corners of the village and through many submersible bore wells at different locations of the village. Apart from this, some of households have installed their own bore wells for withdrawing ground water.

Study population

The total population of the village consited of 1,341 permanent residents, comprising 751 males and 590 females (as per Annual Health survey). The main occupations of the residents of the village were farming, agriculture labour and domesticating animals at their homes.

Data collection

The investigation team conducted a house to house survey between 21 to 29 July, 2018 by covering all the households of the village using a specially designed Case Record Performa (CRF) developed by the investigators. Verbal consents were taken from the respondents. A case definition of diarrhoea as having three or more loose stools in an individual over a period of 24 hours in preceding three weeks was taken to identify cases [22,23].

The CRF contained information regarding diarrhoea, date of onset, frequency of loose stools, presence of abdominal pain, fever, vomiting and nature of treatment undertaken, if any, history of hospitalization in any health facility due to diarrhoea including current admission with duration (Supplementary Table 1). The respondents were also questioned about food eaten outside their homes in the week preceding the illness, a history of travel outside the village and similar illness in other family members in the preceding week. The questionnaire also contained information on the source of drinking water for each household including use of any filters and storage of drinking water with duration. Contribution by ecological factors was also assessed.

The investigation was carried out with the approval of district health authorities. Special ethical clearance for this outbreak investigation was not sought, since the investigators were part of the district surveillance team under Chief Medical Officer (CMO) of Ambala district.

All the public taps and water sources in the village were mapped. The information regarding drinking water for each household was linked to the tube wells supplying the household. The water supply network of the entire village was mapped by walking over the pipelines and information was collected regarding breaks in the pipelines in the past as well as subsequent repairs and closures. Sewage disposal of the village was surveyed and places with evidence of faecal contamination were also mapped by direct observation.

The amount of bleaching powder added to disinfect the water was ascertained by enquiring the tube well operators, responsible for opening the tube wells to supply water through the pipelines, chlorinating water supplied through the tube wells and opening the valves of the distribution system. Information was also obtained regarding the timing of pumping, the amount of bleaching powder added (both normally and during the outbreak) and the standing time for water to mix with bleaching powder.

Apart from intensive surveillance for new cases, water samples were also collected for microbiological assessment. These samples were collected from each of the two tube wells before and after chlorination, seven functional submersible bore wells inside the village, water of which was being used for drinking purpose and ten randomly selected households in the distribution line of two tube wells from different locations in the village. Stored water being utilized for drinking purpose in the selected households were also tested. Water samples were tested for presumptive coliform counts using Most Probable Number (MPN) count method and for the presence of V. Cholera using previously described methods [18]. These samples were sent to Department of Microbiology, PGIMER by the research team for further processing within 2-3 hours of collection and were tested there.

Over the duration of the outbreak, the local health authorities organized daily camps in the village for treating the cases by providing free medications and referred patients requiring rehydration to the local PHC and Community Health Centre (CHC). The community was advised to boil the drinking water and were distributed Oral Rehydration Solutions (ORS) and zinc tablets by the RRT.

Ethical consideration

This study was conducted as an emergency response to the diarrhoea outbreak in a village and was designed to provide information to orient the public health response and 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 participant of each household after detailed explanation of the existence of an outbreak, the objective of the study and the planned use of the information. Moreover, health education was carried out in each household regarding transmission of diarrhoeal disease and its prevention. The information was entered and analyzed anonymously. The study was implemented in collaboration with the local administrative machinery including the district health officials after obtaining authorization to carry out the survey.

Statistical analysis

Data were entered and analyzed in Microsoft Excel sheets. The results were described in frequencies and proportions.

Results

A total of 624 individuals could be contacted and interviewed during the house to house survey. Out of these, 118 individuals gave history of acute watery diarrhea as per the case definition (in the preceding three weeks) giving an overall attack rate of 18.9%.

Distribution by time

The index case, a male aged 23 years, had onset of diarrhea since 18 July, 2018. He was admitted firstly at the local CHC and thereafter, at a tertiary care medical institute and died on 20 July, 2018 at the medical institute. The epidemic curve as per date of onset of diarrhoea among the cases is plotted in Fig.1. Maximum cases had onset of diarrhea between 15 July, 2018 to 21st July, 2018 with no cases being reported after 24 July, 2018.

Passive surveillance of diarrhoea cases was continued for the next two weeks with the help of ASHAs & the ANMs, the Community health workers till no new cases were found.

Place distribution

A transect walk was conducted and a village social map was drawn including area of village supplied by

Table 1. Age and Sex distribution of diarrhea cases in Nakhrauli village, North India (N = 118).

Age group (years)	Males, N (%)	Females, N (%)	Total, N (%)
< 1	1 (0.8)	0 (0.0)	1 (0.8)
1-4	3 (2.6)	1 (0.8)	4 (3.4)
5-14	7 (5.9)	8 (6.8)	15 (12.7)
15-44	24 (20.3)	35 (29.6)	59 (50.0)
45-59	10 (8.5)	9 (8.1)	19 (16.1)
≥ 60	12 (10.2)	11 (9.3)	23 (19.5)
Total	**57 (48.3)**	**61 (51.7)**	**118 (100)**

the two tube wells. All diarrhoea cases were plotted on the map and it was found that a greater number of cases were found in the distribution line of tube well no.2 (48 *vs*. 11 of the plotted cases) as compared to tube well no. 1.

Person distribution

Out of the 118 cases, 57 (48.3%) were males and 61 (51.7%) were females showing both the genders were affected equally by the outbreak.

The outbreak affected all the age-groups with maximum no. of cases (50.0%) being seen in the age group 15-44 years (Table 1)

With respect to various symptoms, abdominal pain and nausea/vomiting were the most common presentation among the diarrhoea cases apart from loose stools (Table 2).

Exposure to various risk for diarrhoea was also assessed. Persons who were using any filtration methods like Reverse Osmosis or other water purifiers were least affected during the outbreak with only 24 (18.2%) cases reported to use any filters for drinking water (Table 3). Open air defecation was found to be practiced by many families in the village.

Laboratory analysis

Three stool samples collected during the outbreak from the cases having diarrhoea were sent for culture at district IDSP laboratory at Civil hospital, Ambala. Two of the samples grew coliforms (*E. coli*) and one sample, of a 13-year-old boy who was later hospitalized, was found positive for *Vibrio cholerae* O1 with positive agglutination with poly O antisera (Ogawa, Inaba). The stool sample of the cholera positive case was also sent to the referral laboratory at department of Medical Microbiology, PGIMER, Chandigarh where the isolates were confirmed as *V. Cholerae* O1, biotype El Tor, serotype Ogawa.

Table 2. Clinical and laboratory characteristics of the diarrhoea cases (N = 118).

Symptom/variables	N (%)
Loose stools	118 (100)
Abdominal pain	64 (54.2)
Nausea / Vomiting	42 (35.6)
Fever	22 (18.6)
Blood in stools	1 (0.8)
Took OPD consultation	86 (72.8)
Admission/Hospitalization	18 (15.2)
Mean (SD) days of illness	2.58 (1.56)
Mean (SD) days of Hospitalization among admitted cases	3.24 (1.89)
Stool samples tested	3 (4.24)
Stool samples positive for *V. Cholera*	1 (-)
Stool samples positive for *E. coli*	2 (-)

Table 3. Exposure to various risk factors among cases of acute watery diarrhoea (N = 118).

Sl. No.	Risk factors	N (%)
1	Not using any filtration method or purifier	84 (81.8)
2	Using stored water for drinking	82 (69.8)
3	Presence of gross contamination in the stored water used for drinking	16 (3.6)
4	History of travel	6 (5.1)
5	Attended any mass gathering or function	0 (0.0)

Stool samples and rectal swabs collected from patients having history of loose stools after the outbreak by the research team was negative for *Vibrio cholerae* or any other pathogenic organisms.

Water samples from one the tube wells where clustering of the cases was observed grown coliforms and had high level of contamination (MPN count > 180). Water sample from the other tube well was found to be satisfactory. Similarly, water samples from all the seven submersible bore wells were found unfit for drinking. Most of the household samples were having inadequate residual chlorination and were unfit for drinking.

Organisms isolated from the water samples tested consisted of *E. coli, Klebsella* sp., *Enterobacter* sp., *Staphylococcus* sp. and *Aeromonas* sp. but none of the samples grew *V. cholerae*.

Discussion

More than 150 years after John Snow removed the Broad Street pump handle in London and used the term "shoe leather epidemiology" for investigating the cholera outbreak, outbreaks of cholera continue to be reported worldwide [15]. The term shoe-leather epidemiology, synonymous with field epidemiology or intervention epidemiology, imply investigations initiated in response to urgent public health problems and for which the investigative team does much of its work in the field [23].

In the present outbreak, bacteriological examination of stool revealed *V. Cholerae* O1, biotype El Tor, Serotype Ogawa as the causative organism. Other studies from India [8-17,20,21] have also identified the same strain as the causative organism of diarrhoea outbreaks in the recent past. However, *V. Cholerae* 0139 strain was the causative organism isolated from the municipal water supply during an epidemic of diarrhoea in a town of South India [18].

In the present study, age-specific attack rate was highest in the most productive age group, i.e. 15–44 years. Similar observations were made by Singh *et al*. in their study [20]. Only one child in the age group of less than 1 year was affected. The reason for this could

be the fact that infants are mainly fed on breast milk and are given less drinking water.

Open air defecation and disposal of sewage water in open drains and spaces, though hazardous, are commonly practiced in rural North India. Thus, platform for an outbreak is always set at such sites. This particular balance can get easily disturbed by the natural events like heavy rainfall, which may lead to the contamination of drinking water in high dose [13]. A similar scenario was present at the village in our study. There was a history of heavy rains 2-3 days before appearance of cases of diarrhoea. The epidemic curve of the outbreak showed peak on the 7th day (Figure 1). Different distributions of incubation periods in differently susceptible individuals and the bacterial dose can be the reason for this kind of epidemic curve.

Results of water samples suggested that the cases had contracted the disease after consuming the contaminated water supplied by the tube wells as villagers using filters such as RO or using water from personal bore wells for drinking were least affected. The immediate remedial action was taken by the research team at 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 diarrhea cases by house to house survey by the RRT, prompt treatment of the cases, distribution of ORS packets and zinc tablets, water sampling of the other water sources, super chlorination of the tube wells and stopping the use of submersible bore wells having high level of contamination for drinking purpose. With all these efforts, number of cases declined rapidly.

Ageing subterranean pipelines with multiple breakages and leakages are a common phenomenon in India. 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. Thus, mixing of sewage with water could potentially occur at multiple points [19]. In most parts of India, the water supply is intermittent, thereby increasing 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. This may have been the case in this outbreak where the number of cases suddenly increased following rainfall.

Contaminated water remains the prime vehicle for outbreaks of cholera in developing countries like India.

Chlorination of drinking water has been recommended as a standard intervention procedure in the control of diarrhoeal diseases. For effective control of cholera outbreaks, the WHO has recommended a residual chlorine content of 0.5 ppm [25]. However, the adequacy of these standards in the Indian context is arguable. In a study performed in southern India, *V. Cholerae* could be grown from seeded tap water in which up to 1 ppm residual chlorine was present [18]. In our study, the amount of bleaching powder added by the tube well operators were found to be grossly inadequate as per the WHO standards during the outbreak. It was also found to be irregular in the pre-outbreak period and in the post outbreak period despite occurrence of the outbreak. It is important to note that cases continued to occur despite the intervention from the district health authorities, and water contamination continued to be present in the tube wells even after 2 weeks of institution of intervention measures. Further, water samples collected after the outbreak from the taps in different locations of the village supplied by the tube wells still showed high levels of contamination reflecting inadequate chlorination at the source.

In rural areas in India, water disinfection relies on single point chlorination at the supply from the tube wells. A study in Ecuador showed that central chlorination of the municipal water system was not sufficient in maintaining adequate free chlorine residuals at the peripheral distribution sites [26]. Booster chlorination at different points of the water supply system may be a better option [27] and the use of spatial information provided by studies like current one would be a useful adjunct to the decision-making process. Point-of-use disinfection techniques are options that have proved to be effective [28-29] and may be applicable in India.

Unavailability of potable drinking water for a large proportion of the Indian population is a major public health challenge. National surveys have shown that only 42% of the households in India have piped water supply as a source of drinking water [30]. Further, studies from urban India have often found piped water to be unfit for human consumption [8,31,32]. Additionally, the proportion of people having access to improved sanitation facility such as availability of sanitary latrines remains a great challenge. Improper sanitary conditions lead to outbreaks of waterborne diseases [33]. From a dismal 7% in 1990, this figure has only improved up to 31% by the year 2008 [30].

Indiscriminate defecation by some families in areas through which the water supply pipes ran, inadequate chlorination of the supplied drinking water from tube wells, poor maintenance of water supply pipes having leakages at multiple sites, parallel sewage and water channels, use of tullu pumps to draw water from main water supply, unhygienic practices such use of pipes for collecting water from public taps going inside the toilets in many places, and heavy rainfall, acting as trigger event, may all have contributed to this outbreak.

Limitations

Limited number of stool samples were collected for microbiological examination due to paucity of resources. Secondly, the investigation was started when the outbreak was on decline limiting fresh number of cases available for stool sample collection and examination. Thirdly, other causes acting either together or on their own to cause the outbreak could not be excluded. Fourthly, on asymptomatic persons, stool examination was not carried out. Lastly, the chlorine levels were determined at the source i.e. tube wells immediately after chlorination and hence residual chlorine level were not assessed. Only qualitative assessment of the chlorination was done. However, these limitations had little impact on validity of the study findings.

Conclusions

It is concluded that the current diarrhoeal outbreak confined to population of a single village was due to consumption of contamination water from tube wells, which were contaminated, probably, through the mixing of sewage with drinking water following heavy rains. *Vibrio cholerae* 01 El Tor, Ogawa serotype, was identified to be the probable causative organism by stool culture. Absence of water filtration methods by the villagers, improper storage of drinking water, and poor sanitation and hygiene practices such as open defecation and use of tullu pumps worsened the situation causing a rapid increase in the number of cases during the outbreak. Prompt actions by the RRT and the local authorities helped in the containment of the outbreak.

Recommendations

The districts should strengthen the integrated diseases surveillance programme system (IDSP) to be able to detect outbreaks in a timely way and institute control measures. A proper surveillance system for early identification of cases along with continued health education will help in initiating and implementing prompt control measures in case of similar outbreaks in future.

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Annex – Supplementary Items

Supplementary Table 1. Case record Performa for investigating the diarrhoea outbreak in Nakhrauli village, North India

S. No.	Name	Age /Sex	Head of household	Contact number	Total family members	Diarrhoea			Abdominal. Pain (Y/N)	Vomiting		Fever (Y/N)	OPD treatment (Y/N)	Hospitalization (Y/N) with No. of Days	Water Source	Use of Filter (Y/N)	Storage (Y/N) Days	Gross contamination (Y/N)	Travel history (Y/N)	Attended any gathering (Y/N)
						Stool type	Onset Date	Episodes /day		Onset Date	Episodes/ day									
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Y: Yes; N: No.