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An acute gastroenteritis outbreak associated with a contaminated water supply system, Turkey, 2018

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ABSTRACT

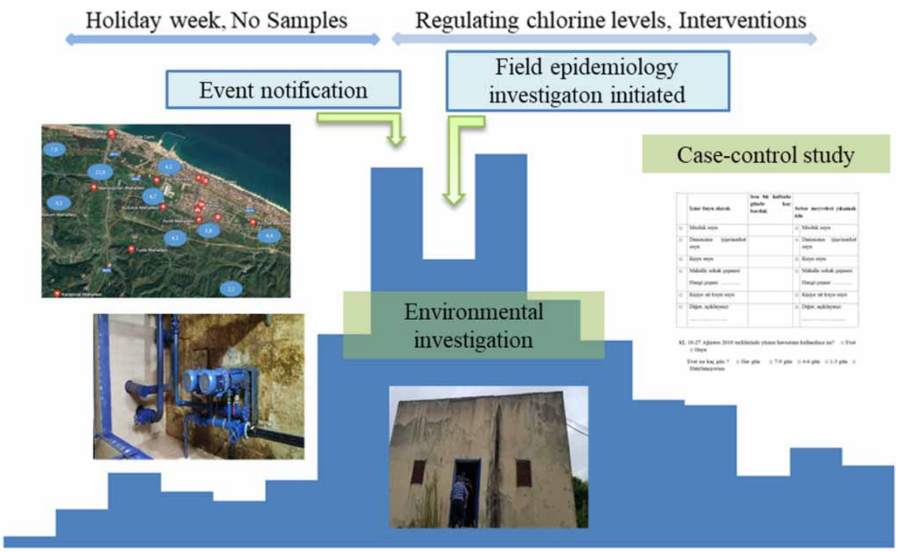
Disruption of routine monitorization and chlorination of the water supply system during a week-long holiday led to a multi-organism gastroenteritis outbreak in a district with limited laboratory support. More than a 10-fold increase in patients with gastroenteritis was reported. Enteropathogenic *Escherichia coli*, Enteroaggregative *E. coli*, and norovirus were detected in human specimen samples. The main water tank and pipes were rusted; 13 out of the 19 water samples tested positive for total Coliform (1–920 colony-forming units (CFU)/100 ml) and *E. coli* (1–720 CFU/100 ml). Chlorine levels were below 0.2 ppm in seven of the nine samples. Information of 1,815 cases was obtained from the hospital records with a crude attack rate of 2.9%. Cases widespread in the district increased throughout the holiday, epidemic curve revealed a point-source outbreak. The case–control study revealed that consumption of drinking tap water and using it to clean vegetables/fruits were significantly associated with the illness. While drinking only bottled water had a protective effect against the illness. The culture technique showed that the water supply samples were positive for pathogenic bacteria. Upon decision in a multi-stakeholder meeting, the water tank was cleaned, and the Municipality initiated the renovation of the water supply system.

Key words: epidemiology, outbreak investigation, waterborne infections, water supply system contamination

HIGHLIGHTS

- Disruption of chlorination and infrequent monitoring occurred during a week-long holiday.
- Water supply samples were tested positive for pathogenic bacteria indicating fecal contamination.
- Epidemiological investigation aided the rural area with limited health service and laboratory support.
- Multi-stakeholder intervention was implemented to disinfect and renovate the water supply system.

GRAPHICAL ABSTRACT



INTRODUCTION

In Turkey, provincial health directorates report notifications of suspected outbreaks on an online event reporting system as part of the Acute Gastroenteritis Syndromic Surveillance. Also, routine electronic datasets of gastroenteritis-related International Classification of Disease (ICD) codes from health centers are registered in real-time and screened daily for gastrointestinal outbreak detection both on provincial and central levels based on cumulative sums, to analyze aberrations of the time series. The Early Warning and Response Unit of the Communicable Diseases and Early Warning Department manages this signal and event reporting system at the central level. C1, C2, and C3 signals are based on short-term baselines and the C4 signal is based on longer baselines. We received the first alert of C2–C3 signals on August 20 and C4 on August 21. The alert continued throughout the week. This alert happened during a holiday called Kurban Bayramı (Eid al-Adha), which means the 'feast of sacrifice.' It is one of the two major religious holidays in the region. Bayram is the term used in Turkey for the holiday, celebrated nationwide, both official and religious; schools, government offices, public health centers, family medicine centers, and hospital clinics are closed except for the emergency services. Families visit each other; meat is usually consumed, and kissing the hands of the elderly and placing it on the forehead is a custom to show respect and greet them for Bayram. For the year 2018, Bayram started on Monday, August 20. On the last day of Bayram (August 24), the provincial health directorate reported more than a 10-fold increase in cases with gastroenteritis in the Emergency Room (ER) of the local public hospital, the only health center in the district available during the holiday.

The provincial office had not determined the source of the increase in patients with gastroenteritis and requested aid from the central level. We initiated an epidemiological investigation to identify the possible source and implement control measures to stop the outbreak. The Field Epidemiology team conducted this outbreak investigation coordinated together with the Provincial Health Directorate and the Environmental Health office.

MATERIALS AND METHODS

Historical review of the outbreak

We reviewed the local hospital's gastroenteritis-related ICD-10 codes and electronic datasets (including patient's age, location, and symptoms). Commonly used ICD-10 codes may differ between physicians and hospitals. We contacted the medical doctors working at this local ER during Bayram and learned that the physicians used two codes for acute gastroenteritis patients: R11 (nausea and vomiting) and K52 (other noninfective gastroenteritis and colitis).

Case finding

We wanted to choose from hospital admissions with diarrhea and vomiting to reach a more refined case group for the study. However, symptoms were not noted systematically in the patient record system; therefore, we used ICD-10 codes.

Case–control study

We conducted a case–control study. A suspected case was a Karasu resident diagnosed with either of the gastroenteritis-related ICD-10 codes (R11, K52) during August 20–27; we conducted the case–control study among 175 randomly selected cases and their controls. A control was a neighbor who did not have gastroenteritis-related symptoms during August 20–27. Face-to-face interviews included questions on socio-demographic characteristics, hygiene habits, and sections on potential exposures such as food consumption, water consumption, swimming, involvement in a mass social gathering, noticing 'bad odor/taste/color' of water, and experiencing a water shortage. We compared exposures of case-patients with neighborhood control-persons to calculate the odds ratio (OR) and 95% confidence interval (CI). Differences were considered significant if the p-value was <0.05. SPSS 15.0 and R software were used for the analyses.

Human laboratory investigation

Because the hospital could not perform analysis on stool samples, no samples were taken during the peak of the outbreak. We requested ER clinicians to take stool specimens for pathogenic bacteria (*Campylobacter*, *Salmonella*, *Shigella*, and *Yersinia*) and enteric viruses (adenovirus, rotavirus, and norovirus) to be sent to the central laboratory. Six stool samples were taken. Samples were analyzed at the National Reference Laboratory using culture methods and polymerase chain reaction (PCR).

Environmental investigation

We collected information about social events, gatherings, and consumption of food. We visited water tanks to collect water samples, inspected the tanks' physical state, and checked the chlorine levels. We collected 19 water samples from the district's water distribution system between 24 and 26 August 2018. Samples were tested in the Provincial Public Health Laboratory for bacteria indicating fecal contamination (*Escherichia coli*, total coliforms, enterococci, aerobic microorganisms). Provincial Public Health Laboratory could only perform culture methods for microbiological analyses of water. The National Reference Laboratory analyzed 4×100 l water samples for virus detection using RT-PCR.

RESULTS AND DISCUSSION

Globally, the disease burden from water sanitation and hygiene is estimated to be 5.7% of the total disease burden, and infectious gastroenteritis is attributed as the primary cause of that burden (Prüss *et al.* 2002). Human sewage and animal waste polluting water distribution systems are extensive sources resulting in fecal contamination of drinking water, leading to the waterborne transmission of enteric pathogens (Park *et al.* 2018). Bacterial agents, such as diarrhoeagenic *E. coli*, *Campylobacter jejuni*, and *Shigella sonnei*, are known pathogens that may contaminate water, causing bacterial gastroenteritis, which is encountered more in developing countries compared to the developed ones. As for the causes of viral gastroenteritis, noroviruses and rotaviruses are the most common pathogens (Leclerc *et al.* 2002; Jain & Jain 2014). Multi-pathogen gastroenteritis outbreaks are common in Turkey caused by drinking contaminated water, and prevalent pathogens, such as *E. coli* and norovirus, may lead to waterborne outbreaks in Turkey (Sezen *et al.* 2015; Şahan *et al.* 2017; Özgüler *et al.* 2019). For low- and middle-income regions, water supply systems of rural areas are assessed to have shown higher contaminations with enteric pathogens compared to urban areas. Evidence-based interventions can reduce the burden of gastroenteric diseases in middle-income countries (Baum *et al.* 2013). Elimination of contaminants from drinking water before human consumption and monitorization is indispensable for securing safe water (Breitenmoser *et al.* 2011).

Descriptive study results

Information on 1,815 cases was obtained from the hospital records of the district (population: 62,866). The attack rate was 2.9% (1.7% for female and 1.2% for male). However, as this attack rate was calculated using hospital admissions, this could reasonably underestimate the real attack rate when symptoms are broad and non-severe, as is the case for gastroenteritis. During the holiday period, increased patient volumes are expected at the ER (Dagar *et al.* 2014). We compared the current admissions with previous years' same dates and prior years' Bayram period (which changes according to the lunar calendar) to verify the outbreak. The most common symptoms were diarrhea and vomiting, and attack rates between females and males were similar, consistent with studies alike (Huerta *et al.* 2000; Duman *et al.* 2016; Park *et al.* 2018). The absence of single-source food consumption, mass gatherings, or significant social events, along with cases being spread without neighborhood clustering, led us to consider water as the possible source of this outbreak. Figure 1 shows that case numbers peaked, the central unit was deployed to do field investigation, and cases started to decline after interventions; the epidemic curve resembled a point-source outbreak.

Case–control study results

Tap water was found to be associated with the disease; of the cases, 74.3% (130/175) drank tap water, compared with 62.3% (109/175) of controls (OR = 1.8, 95% CI = 1.1–2.8; $p = 0.02$). Consuming only bottled water had a protective effect against the disease; of the cases, 14.2% (25/175) drank only bottled water, compared with 26.2% (46/175) of controls (OR = 0.5, 95% CI = 0.3–0.8; $p = 0.005$). The other two things that we found to be associated with the disease were using tap water to clean the fruits/vegetables and noticing a bad odor from the tap water. Of the cases, 97.1% (170/175) used tap water to clean fruits and vegetables, compared with 90.9% (159/175) of controls (OR = 3.4, 95% CI = 1.2–9.6; $p = 0.01$). Of the cases, 34.9% (61/175) noticed a bad odor from the tap water, compared with 25.1% (44/175) of controls (OR = 1.68, 95% CI = 1.05–2.69; $p = 0.03$). Of the cases, 81.1% (142/175) other people that fit the case definition at their homes, compared with 53.1% (93/175) of controls (OR = 3.4, 95% CI = 1.2–9.6; $p = 0.01$). The rest of the included variables, such as hygiene habits, water shortage, food consumption, swimming, attending a mass social gathering, and noticing 'bad taste/color' of tap water, did not significantly differ between cases and controls.

Human laboratory investigation

We obtained the results of six stool samples for culture and PCR. The culture result for one sample was positive for Enteropathogenic *E. coli* (EPEC) and one for Enteroaggregative *E. coli* (EAgEC). In-house PCR results were negative for four specimens; one specimen was positive for Enterohemorrhagic *E. coli* (EHEC) and the other for EAgEC. Two samples were positive for norovirus among the three specimens tested using Biofire PCR.

Environmental investigation

We visited the Metropolitan Municipality Water and Sewerage Administration to get information and water tanks to observe the current situation. Water was gathered from nine catchments (springs) and one stream and treated in a drinking water treatment plant. This water treatment process included pre-settlement, adsorption, and sand filters. The water moved to the main water tank from the plant, where it received chlorination. The main water tank had an automated chlorine device. During our visit, we observed that the main water tank and pipes were in bad condition; the stairs going inside the tank were rusty, and there was no safety band around the tank. All but one of the neighborhoods' water was distributed

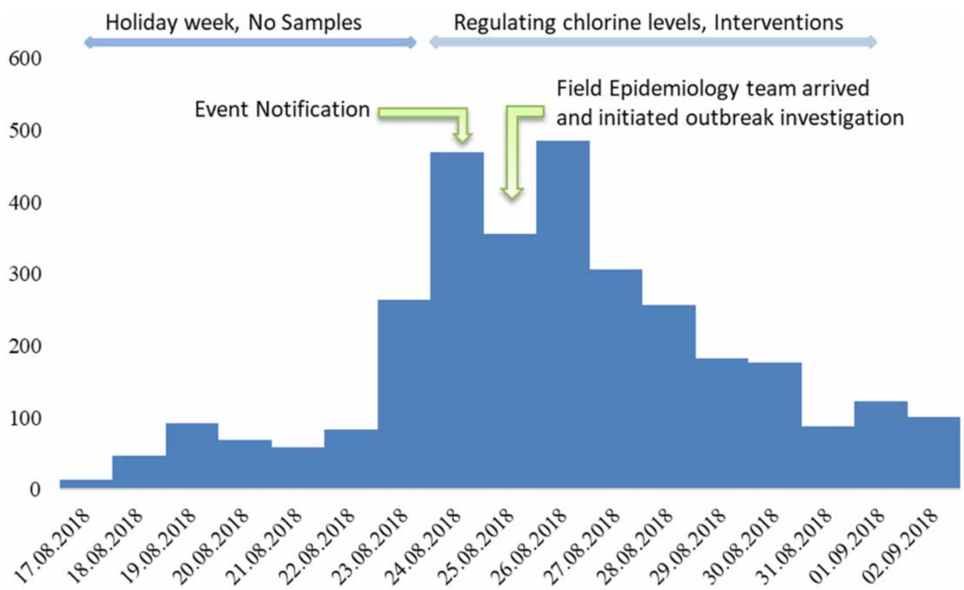


Figure 1 | Epidemic curve using daily hospital ER admissions of gastroenteritis-related cases.

directly from this tank to the system. Only one neighborhood's water was sent to a secondary tank (400 tons capacity) and distributed from there. The secondary tank did not have a chlorine device, and we were informed that it was used for logistic reasons (to facilitate water distribution). This neighborhood's attack rate (3.7%) was similar to other neighborhoods' attack rates (mean 3.7, SD: 3.1). Thirteen water samples of the water supply system, including two catchments and one from inside the main water tank supplying the whole district, tested positive (>1 colony-forming units (CFU)/100 ml) for total Coliform (1–920 CFU/100 ml) and *E. coli* (1–720 CFU/100 ml).

Municipality Water and Sewerage Administrations are responsible for the treatment and distribution of water for human usage. Also, provincial health directorates are responsible for inspecting and monitoring the water supply system. According to district legislation, the accepted free chlorine levels for endpoints (tap water samples) are 0.2–0.5 mg/l. On August 24, seven of the nine water samples gathered from the endpoints had insufficient chlorine levels. Municipality Water and Sewerage Administration informed us that there was an increase in water usage during Bayram, leading to a possibility of water being supplied to the network without the chlorine showing its residual effect. They have explained that this could cause the water to be supplied at endpoints without having the contact time with the minimum required chlorine levels to enable disinfection. Similarly, low chlorine levels were reported during other waterborne outbreaks in Turkey (Duman *et al.* 2016; Özgüler *et al.* 2019). Water sample results indicating contamination related to non-chlorinated water supply and disinfection deficiencies are mentioned for *E. coli* and norovirus outbreaks outside of Turkey as well (Huerta *et al.* 2000; Olsen 2002; Murphy *et al.* 2016; Park *et al.* 2018). We were notified that routine water inspection was interrupted during Bayram, while 14 out of the 15 samples taken before the holiday had insufficient chlorine levels but were not followed up. On August 25, during our visit (after chlorination), the main tank's chlorine level was 0.7–1 ppm and the secondary tank was 0.1–0.2 ppm. Waterborne norovirus and *E. coli*-related outbreaks, similar to this one, emphasize the importance of monitoring the water supply network for infectious pathogens and advanced laboratory analysis at local levels to understand the cause better and implement evidence-based and timely interventions (Maunula *et al.* 2005; Magana-Arachchi & Wanigatunge 2020).

Limitations

Public Health laboratories (responsible for the analysis of water samples) of the province and neighboring provinces did not have PCR were not providing any analysis for viruses or serotype analysis for bacteria. The province did not take the samples during the outbreak until the investigation team arrived and the water was treated. Water samples were sent to the central laboratory for the detection of viruses, which caused both logistic and workforce limitations as it has a high workload and is located in a different city. This caused samples to be taken late and in small quantities. Source, transmission route, and the mechanisms of norovirus outbreaks are not often revealed, although it is essential to aid an ongoing outbreak and limit future outbreaks (Bitler *et al.* 2013). The true extent of waterborne outbreaks is challenging to determine in such areas as the capability to identify the organism and the transmission ways are limited. Detecting pathogens in water is significantly more challenging than in human samples, which led us to depend on the epidemiological investigation (Kulinkina *et al.* 2016).

Control measures

We held two multi-stakeholder meetings for multi-focal interventions. When the water supply is contaminated by pathogens, as in our situation, public health agencies and related sectors need to be actors in rapid detection and response to control waterborne outbreaks (Benedict 2017) Decisions were made as follows: to inform the public about the disease and related hygiene practices, to carry on routine chlorination and routine sampling uninterruptedly during holidays, to get samples from water tanks and endpoints outside of the routine sampling points until the end of the outbreak, to inspect and report what needs to be corrected and what is found to be inappropriate. The main water tank was cleaned and chlorinated according to the recommendations of the environmental health office consultants. A chlorine device was implemented in the secondary water tank. Family medicine practitioners informed their patients about the outbreak. We conducted health education on safe water consumption and hygiene practices to prevent household transmission. The public was advised not to use pools if they had gastroenteritis-related symptoms to prevent secondary infections. The environmental health unit collected 39 water samples outside the routine sampling points and the tanks after the interventions. All had adequate chlorine levels (>0.2 ppm) and no detected pathogens. Renewal of the main tank and water pipes has been initiated and progress is monitored. The district has not reported similar waterborne outbreaks on the early warning and response system's acute gastroenteritis surveillance component to this date.

CONCLUSIONS

Tap water was positively associated with the disease while drinking only bottled water had a protective effect against the disease. Using tap water to clean the fruits/vegetables and noticing a bad odor from the tap water were also positively associated with the disease. Moreover, the epidemic curve revealed a point-source outbreak leading us to view the water supply network as the probable source. Human sample results revealed *E. coli* subtypes and norovirus. Additionally, the main water tank's condition was not compatible with the legislation and the second tank did not have a chlorination device. The main tank's chlorine levels were appropriate during our visit, but we were told no samples were taken during Bayram. Seven of the nine water samples gathered from the endpoints had insufficient chlorine levels. Thirteen water samples tested positive for total Coliform and *E. coli*. Epidemiological and environmental investigations pointed toward the contamination of water distribution systems with enteric pathogens. Although norovirus was not detected in water samples, the clinicians who were on duty during Bayram had opinioned that some patients were more likely to have norovirus. Hence, we did not remove it as a possible agent co-causing this outbreak along with *E. coli*. Contamination in the water supply may have broad effects on public health, yet it can be prevented by correct water treatment and regulations. Upon decision in a multi-stakeholder meeting, the water tank was disinfected. The Municipality started to renew the water system, which had already begun during our follow-up the following year. Health education on the outbreak, including related hygiene practices and safe water consumption, was also conducted.

Although we could not detect the exact time and origin of the contamination causing this outbreak, it was revealed that the water supply system was overwhelmed during the holiday, and the routine water quality monitoring was interrupted. As national holidays may cause changes in local populations' activities and water usage, monitoring the water supplement systems should carry on without a break, and samples should be collected and analyzed promptly, especially during the holidays. Rapid detection, laboratory support for identifying the source, and evidence-based interventions can reduce transmissions. Therefore, continuous water quality surveillance and monitoring case trends are crucial to detect inclines in waterborne infections and prevent outbreaks promptly.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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