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ORIGINAL ARTICLES AND REVIEWS

Community waterborne outbreak linked to a firefighting response during the COVID-19 emergency

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Abstract

Background. On 6 March 2020, a big fire in a village forced the firefighters to draw water simultaneously from many sources, including the Adige river. From 9 March, an increasing number of inhabitants reported gastrointestinal symptoms. We describe the outbreak and the challenges linked to the concurrent COVID-19 spread.

Methods. Residents with enteric symptoms and their relatives were interviewed and samples from some of the patients and public water pipelines were tested for enteric pathogens with microbiological and molecular methods.

Results. By 20 March, 182 people reported symptoms and 131 met the case definition. Norovirus GI/GII and other pathogens were found in human and water samples.

Conclusions. Contamination of the public water network with sewage-contaminated river water through the firefighters pressurized water tank was the suspected source of the outbreak. The investigation was partly hampered due to the SARS-CoV-2 emergency. Control measures included avoiding tap water, alternative water supplies and chlorination of public water.

Key words

- gastroenteritis
- norovirus
- waterborne diseases
- community outbreak
- COVID-19

BACKGROUND

Waterborne diseases include many different types of infections that are transmitted through contaminated water and viruses, bacteria, protozoa, and helminths can be involved.

Contaminated drinking water may cause large community outbreaks with up to thousands of cases. Raw water contamination, treatment deficiencies, and distribution network failure are among the most common causes of water contamination [1]. In addition to problems with or failure of the water distribution system, heavy rainfalls and floods associated to seasonal trends and climate change can cause water contamination, with runoffs from wastewater treatment plants, and areas with intense agricultural activities [2].

The source of the contamination is most commonly wastewater which may harbor a large number of diverse pathogenic microbes [3].

In Europe waterborne outbreaks are commonly reported, and the most frequently involved pathogens are norovirus, hepatitis A virus, *Campylobacter*, *Salmonella*, pathogenic *Escherichia coli*, *Shigella*, *Cryptosporidium*, but for a proportion of waterborne outbreaks the agent remains unknown [4].

Noroviruses are a leading cause of sporadic cases and outbreaks of acute gastroenteritis. They account for approximately one-fifth of all acute gastroenteritis contributing substantially to the global burden of acute gastroenteritis across all settings and age groups [5].

Norovirus is highly contagious, and the infectious dose can be very low, in the range of 10-100 viral particles [6]. Although less common, waterborne outbreaks of norovirus are reported worldwide and often in association with groundwater contamination and poor chlorination [1, 7, 8].

On 6 March 2020 there was a big fire in a speck factory (typical smoked and spiced ham from South Tyrol, Italy) in the village of Postal (n = 1828 residents; Bolzano Province, Italy).

Firefighters used the hydrants connected to the pub-

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lic water network, but soon they faced water shortage and placed eleven "hydrosub" units in the Adige river, located at about 750 meters from the place of the fire (*Figure 1*). During the operations, firefighters also connected five private wells in the vicinity of the place of the fire.

Car pumps collected water from all the sources and mixed it in a pressurized water tank. The fire was extinguished on 8 March after 2.5 days, but the operations of the firefighters ended on 10 March. Twenty-six teams of firefighters in different shifts were involved in the fire operations, for a total of about 800 firefighters involved. Most of them were volunteers from the village and the neighborhoods.

On 9 March some inhabitants of the village reported to the Mayor changes in the appearance, taste, odor, and color of the tap water, and some consulted the local general practitioners (GPs) for gastroenteric symptoms starting from the evening of 6 March. The largest part of the inhabitants of Postal are used to drink tap water, considered safe and of high quality.

Tap water in the village of Postal, is supplied by the municipality that takes care of collecting, monitoring and distributing drinking water. The water source is ground water collected by a deep well (about 50 meters) located in the south west of the village (*Figure 1*). From the well the ground water is pumped to an elevated tank (*Figure 1*) placed in the eastern side of the village. The houses in the southern part of the village are supplied directly by the well, while those in the northern part receive the water from the tank, through gravity.

On 9 and 10 March the personnel of the local health department collected some samples of the tap water and on 10 March the residents were advised not to consume or use tap water (consumption was allowed only to wash and cook after boiling) and alternative water supplies (bottled potable water) were provided to the population for drinking. The water avoidance notice was extended to 18 March 2020. On 10 March the Local Health Unit started an epidemiological investigation after the reporting of gastrointestinal symptoms

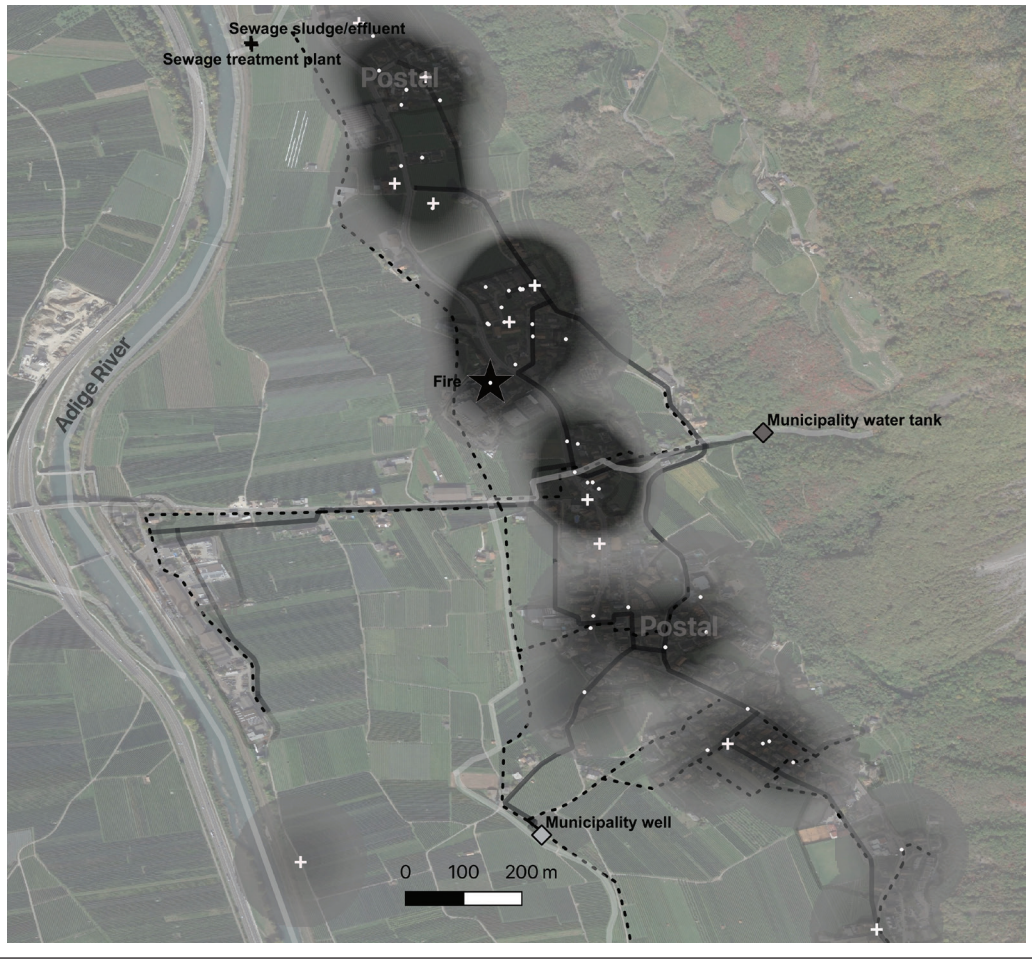

Figure 1
Map of the Village of Postal, North Italy, and density map of the cases of gastroenteritis. The black star is the place of the fire, the small white dots are the residence of the cases (n = 131), the solid dark gray line is the public water system. The density of cases is presented as dark areas; the darker area means higher number of cases. The white crosses are the places from where water samples were taken, the light gray diamond is the ground water deep well and the dark gray diamond is the water tank.

by 50 people, to confirm the outbreak, identify the size and the source.

This outbreak occurred during the beginning of the SARS-CoV2 epidemic in Italy. On 9 March the Italian Government declared COVID-19 a national public health emergency and on 11 March Italy's Prime Minister scaled up the emergency response with extreme measures of personal distancing, including mobility restrictions, banning of mass gatherings, closure of schools and work activities, isolation and quarantine (lockdown). On the same day, the World Health Organization (WHO) declared the SARS-CoV-2 pandemic.

This article describes the epidemiological and microbiological investigations of an acute gastroenteritis outbreak associated with potentially contaminated water during a firefighting response in a small village in Northern Italy. Moreover, we discuss the impact caused by the COVID-19 pandemic on the outbreak investigation and control measures.

METHODS

Epidemiologic investigation

Residents of Postal (Bolzano Province, Italy) who consulted the GPs or contacted the local health unit declaring symptoms referable to a gastroenteritis with onset from 6 March 2020 onwards and their relatives were interviewed by telephone by nurses of the local Public Health Department. A suspected case was defined as a person who had experienced diarrhea (three or more watery stools per day) OR vomiting (three or more times per day) from 6 to 20 March 2020. A confirmed case was a suspected case with a laboratory confirmation of the infection.

Data on clinical symptoms, the time of symptom onset, food consumption and other exposures were collected using the national official questionnaire for the investigation of acute gastroenteritis episodes.

The firefighters who responded to the fire were asked about gastrointestinal or respiratory symptoms (to detect a possible COVID-19 case) up to 14 days after the fire. All sick persons were interviewed.

Microbiological investigation

Stool samples and rectal swabs obtained from the patients were tested for a list of enteric pathogens with both microbiological and molecular methods.

The specimens were sent to the accredited diagnostic laboratory (UNI EN ISO 15189:2013) of the Local Health Unit in Bolzano, and cultured for the detection of *Salmonella, Shigella* and *Campylobacter*, using standard microbiological methods. A commercial multiplex RT–PCR assay was also used for simultaneous detection of *Campylobacter* (*jejuni, coli, upsaliensis*), *Clostridium difficile, Plesiomonas shigelloides, Salmonella* spp., *Yersinia enterocolitica, Vibrio* (*parahaemolyticus, vulnificus, cholerae*), *Shigella* spp., Enterohaemorrhagic *E. coli* (EHEC), Enteropathogenic *E. coli* (EPEC), Enterotoxigenic *E. coli* (ETEC), Shiga-like producing *E. coli* (STEC, stx1/stx2), *E. coli* O157, Enteroaggregative *E. coli* (EAEC), Enteroinvasive *Shigella/E. coli* (EIEC), *Cryptosporidium* spp., *Cyclospora cayetanensis, Entamoeba histolytica, Giardia intestinalis*, Adenovirus F40/41, Astrovirus, Norovirus GI/GII (NoVs), Rotavirus A, Sapovirus (I, II, IV, V) (FilmArray™ GI panel - BioFire Diagnostics, Salt Lake City, UT).

Environmental investigation

In *Figure 1*, the map of the village of Postal is presented, with the place of the fire, the main watercourses, the public water system and the sewage system.

An environmental investigation at the place of the fire, with identification of the water sources used by the firefighters to extinguish the fire was performed by a team composed by local health authority staff, firefighters' representatives and the Mayor.

The investigation included an examination of the well construction log, current well and tank, hydrants and public water network, monitoring records, and potential sources of contamination.

Routine sampling activity of the drinking water was complemented with additional sampling performed to check water quality and presence of contaminants almost daily from 9 to 19 March. Additional samples of 1-Litre of water were collected from the public well, water reservoirs, public fountains and taps along the distribution system (*Figure 1*).

On the 10 March, the filter of the household water filtering system of 2 cases was also sampled.

Bacteriological (revived 36 °C, revived 22 °C, coliforms, faecal Enterococci and *E. coli*), physical and chemical parameters were analysed. The presence of coliform bacteria was daily monitored at several sites of the water system before and after the chlorination treatment.

The analyses of the tap water were performed by the Provincial Agency for the Environment and Climate Protection.

Statistical analysis

Descriptive statistics were calculated for the cases using STATA software version 16.1 (StataCorp 4905 Lakeway Drive College Station, Texas 77845 USA).

The geographical mapping of the cases and the water system, the calculation of the distances matrix between the place of the fire and the cases, and the cases density heatmap were performed using QGIS version 3.10 [9].

RESULTS

Between 6 and 20 March, 2020, 201 people were interviewed by the local health staff, 182 declared symptoms referable to acute gastroenteritis and 131 met the case definition.

Sixty-six (50.4%) were males and sixty-five (49.6%) were females. The median age was 39 years (range 2 to 87 years, interquartile range [IQR] = 20-57 years). Symptom onset was acute, the first confirmed cases of gastroenteritis had their symptoms starting on 6 March, few hours after the firefighters' intervention.

The cases of gastroenteritis followed a steep increment from 6 to 9 March, and the peak occurred on 9 March, with 46 cases (third day after the fire; *Figure 2*). Common symptoms (*Table 1*) were diarrhea (71.76%), vomiting (62.60%), nausea (59.54%), abdominal pain (53.44%), head and joint ache (48.85%), and fever

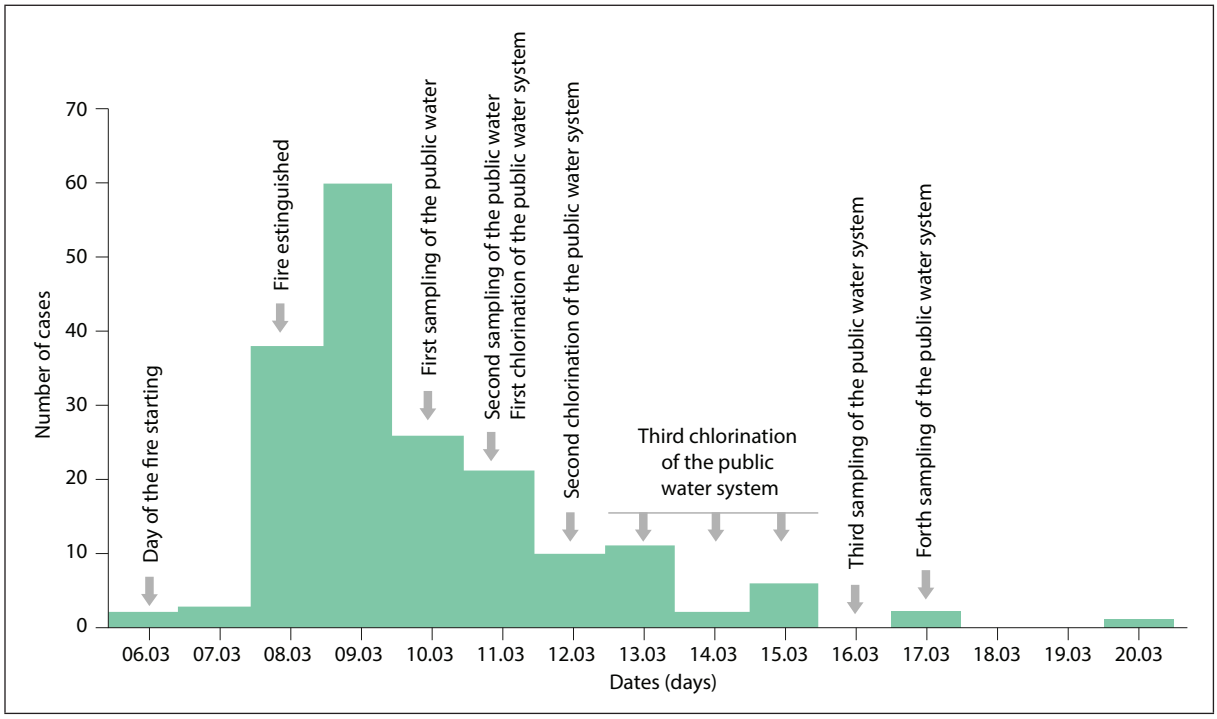

Figure 2
Distribution of the number of cases of gastroenteritis occurred in Postal, North Italy from 6 to 20 March 2020 by date of the onset of the symptoms. The events and the intervention measures put in place by the health authorities are reported by date of occurrence.

(34.35%). The mean incubation period was 72 hours (3 days), and it ranged from 8 hours to 14 days. The median duration of symptoms was 3 days (range 1 to 13 days). One case needed access to an emergency department but was not hospitalized. All the respondents declared usual drinking of tap water in the days before the onset of clinical signs.

The median distance between the place of the fire and the residence was 459.33 meters (IQR=238.72-773.56 meters). It was calculated on 130 cases, because for one case the geographical information was not available. The highest density of cases occurred in the area of the village located at about 300 meters North-East of the fire, followed by two other areas, one at about 650 meters North, and another at about 350 meters South of the fire (*Figure 1*). According to the water system flow, the hot spots North of the fireplace were downstream, while the hotspot South was upstream of the fire.

Due to the National lockdown imposed by the Government, the Local Health Unit and Laboratories reduced their activities. As a consequence, only 18 samples (rectal swab plus stool sample) were collected from the 201 suspected cases.

Among the 18 samples analyzed, twelve were positive for NoVs (66.6%). The molecular characterization showed the presence of two different genogroups: genogroup I (GI) and genogroup II (GII). Seven (38.8%) samples were co-infected (2 norovirus + rotavirus; 2 norovirus + EPEC; 1 norovirus + rotavirus + sapovirus; 1 norovirus + rotavirus + sapovirus + EPEC + EAEC; 1 norovirus + rotavirus + EPEC + EAEC;) and 1 was positive only for rotavirus. Five samples were negative.

The two water samples collected on 10 March and five out of nine water samples taken on 11 March in different points of the water system (*Figure 1*) revealed high concentrations of *E. coli* (>300 colony forming units [CFU]/100mL), Enterococci (>120 CFU/100mL), total coliforms (>300 CFU/100mL), while the chemical parameters were below the limits. The negative samples were those collected at the municipality well and in the southern part of the village.

Norovirus was detected on the filter collected on 10 March in the household water filtering system of two cases.

On 10 March the residents were advised not to consume or use tap water and bottled potable water was

Table 1
Frequency of the symptoms presented by the 131 cases of gastroenteritis in Postal, North Italy

Symptom	Number of cases (131 total)	Frequency (%)
Diarrhea (≥3 loose stools in 24 hrs)	94	71.76
Vomiting (≥3 times in 24 hrs)	82	62.60
Nausea	78	59.54
Abdominal pain	70	53.44
Head/joint ache	64	48.85
Fever (≥37.5 °C)	45	34.35

provided to the population for drinking. The chlorine treatment of the water system started on 11 March and was repeated four times, the last one ended on 15 March. Chlorine concentration of the water supply was then maintained through the whole surveillance period at 0.2 mg/L, corresponding to the currently recommended concentration for waters intended for human consumption in Italy. Twelve out of fourteen water samples taken on 16 and 17 March were negative, and only two samples revealed 1 CFU/100mL, while the five samples collected on 19 March resulted negative. The water avoidance notice was extended up to 18 March 2020.

DISCUSSION

We described an outbreak of gastroenteritis in a small village in Northern Italy that occurred in a close temporal and spatial relationship with a firefighting. We suspected the consumption of water contaminated by river water during fire extinguishing as the source of the outbreak. The outbreak involved at least 131 cases but up to 201 people declared symptoms referable to gastroenteritis in the period from 6 to 20 March 2020.

To our knowledge, this is the second community waterborne outbreak of gastroenteritis associated with firefighting [10].

The sudden onset of symptoms and clinical picture of the illness was suggestive of viral infection, in particular norovirus [11]. Stool samples collected from patients confirmed norovirus genogroups GI and GII. Moreover, norovirus was also detected in the household water filtering system of two cases. Unfortunately, this latter sample was not sequenced more comprehensively to determine Norovirus genotypes.

Norovirus constitutes one of the most frequently identified causative agent of waterborne outbreaks associated with tap water contamination in many countries [1, 12]. In Italy, norovirus outbreaks linked with contaminated drinking water from municipal supplies have already been identified in community settings and touristic resorts [7, 13, 14].

Microbiological investigations identified also other pathogens in the stool samples of patients, and this can explain the 3 days mean incubation period, since the incubation period of several gastrointestinal pathogens can vary from hours to weeks. In waterborne outbreaks multiple aetiologies are common [1], and in outbreaks due to surface water contaminated with sewage, a large number of different pathogens, including bacteria, viruses and parasites, may be involved [15]. Due to the limitations of the laboratory capacities for testing other than SARS-CoV-2 suspected samples, we tested only eighteen stool samples that allowed the confirmation of the Norovirus aetiology and the possible involvement of other pathogens.

Considering the dynamic of the event, we hypothesized an incident during the firefighting on 6 March 2020 that caused the contamination of the public water system, including the elevated tank but not the deep well. This hypothesis is substantiated by the highest density of cases in proximity of the fire and downstream, probably due to the entry of the contaminated water in one or more of the public water network points connected to the firefighters' hydrants (given also the lack of backflow valves in some municipal hydrants). An investigation into the actions taken by firefighters pointed towards the use of contaminated river water drawn right near the sewage pipelines, that from the pressurized water tank used by firefighters to extinguish the fire may have entered into the municipality water system. Infiltrations into the water system or breakages were ruled out by verifying water pipe installations integrity in the area around the fire. However, the cases were also found in different areas of the village, and this may have been caused by contaminated water rising along the pipes up to the municipality tank due to its high pressure, and from here flowing back by gravity into the system.

The actions taken by local health authorities included the provision of an alternative drinking water source and chlorination of the drinking water network. Furthermore, additional hygiene education to reduce the risk of waterborne infections was also provided to all citizens.

Chlorination ability to improve water safety can vary as a function of source water characteristics (e.g. turbidity, pH and temperature), and chlorine characteristics (e.g. concentration and dose) [3, 16].

Moreover, norovirus is resistant to chlorine disinfection when free chlorine levels are inadequate [17] The characteristics of the contamination (river water with sediments and sewage) and the relatively small size of the tank comparing with the pipeline system may have hampered the efficacy of the chlorination. These factors may explain the sporadic microbial findings in water samples after the first chlorination and the need to repeat the treatment.

This study presents some limitations, partly due to the concern of people related to the SARS-CoV-2 emergency and to the lockdown measures implemented by the Italian government. First, we faced a severe limitation in the laboratory testing capacity due to the sudden request of SARS-CoV-2 diagnosis for a large number of suspected cases; second, it was not possible to plan any analytical study to identify individual factors related to the risk of infection, as the local health staff was almost completely dedicated to the SARS-CoV-2 emergency; third, we probably underestimated the number of cases because the local health authorities advised the citizens to limit the visits to hospitals and laboratories to urgent issues, reducing the opportunity to identify those who had mild symptoms of acute gastroenteritis.

Another limitation was the incomplete microbiological investigation of the water, that only included the microbiological parameters according to the Council Directive 1998/83/EC. Fecal or sewage contamination of drinking water is known to result in mixed bacterial and viral infections [18, 19], but the lack of an unified method to encompass the collection and analysis of a water sample for all pathogenic microorganisms of interest make difficult the microbiological screening of the water samples [15, 20].

Finally, we probably missed some cases, in particular among firefighters who were not resident in Postal and

were not interviewed nor sampled. The large number of firefighters involved in the fire made particularly difficult the identification of those potentially exposed and infected.

Amidst the chaotic situation due to the newly implemented lockdown measures, the ongoing gastroenteritis outbreak and the risk of infection and spread of the COVID-19 in the small community, the operations of the local health authorities became extremely complex. However, thanks to the support from the authorities and people's strict adherence to authorities' advices, the situation was maintained under control and more serious consequences were avoided.

Several improvements can be recommended, taking into account the outbreak dynamic. Operational guidelines and training for the firefighter volunteers on the use of the hydrosub units and the health risks related to contaminated water during fire operations should be advised. Improvements in the water system sanitization procedures to increase the efficacy of the chlorination interventions and reduce the time required to effective sanitization of the water are also advised, as the implementation of reflux valves in hydrants. A more thorough microbiological investigation of the water in case of suspected waterborne outbreak should be considered, in particular when the involvement of multiple pathogens cannot be excluded.

In conclusion, we described a waterborne community outbreak potentially related to a fire incident in a small village in Northern Italy occurred during the beginning of the SARS-CoV2 emergency, and we commented on the special difficulties encountered during the investigation due to this concomitant event.

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Conflict of interest statement

None declared.

Authors' contributions

SN coordinated the epidemiological investigation, collected the data from the different sources, undertook the search and interpreted data for the work. FB coordinated the environmental investigation and collected the data from the field. AS provided environmental data and contributed to the environmental investigation. RO provided clinical information on cases and revised the manuscript. LB made data analyses and mapping. SN and LB wrote the manuscript. DR supervised the investigation and revised the manuscript. All authors read and approved the final manuscript.

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