

AN INVESTIGATION OF A WATERBORNE OUTBREAK CAUSED BY MICROBIOLOGICAL CONTAMINATION OF THE DRINKING WATER SUPPLY SYSTEM

PREISKAVA HIDRIČNEGA IZBRUHA, POVZROČENEGA Z MIKROBIOLOŠKO KONTAMINACIJO PITNE VODE

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Abstract

Background: An outbreak of acute gastroenteritis occurred in March and April 2010 in the town of Mengeš where drinking tap water was contaminated, affecting an area with 3000 residents. The aim was to assess the extent of the outbreak, identify the etiological agents and test the hypothesis that drinking unboiled water from the distribution system was the vehicle for the outbreak, and if necessary to initiate appropriate control measures.

Methods: A retrospective cohort study including 160 randomly selected households (20% of the affected residents) was conducted. A case was a resident of Mengeš developing either diarrhoea, vomiting or abdominal pain.

Results: The overall attack rate was 31.3%. The epidemic curve showed a clear peak in the number of cases suggesting a common point source exposure. Residents who consumed unboiled tap water were 4.8 times (95% CI 0.7-32.7) more likely to become ill than the non-exposed. Drinking unboiled water, brushing teeth and eating raw fruit and vegetables washed with unboiled tap water was associated with gastroenteritis (RR 3.1 (CI 95% 1.5-6.5), 3.1 (CI 95% 1.2-8.1) and 2.3 (CI 95% 1.2-4.3)). There was a dose-response relationship between the volume of unboiled tap water drunk and the attack rate among the residents. Norovirus and Rotavirus were detected in the water samples, as well as in stool samples from the cases.

Conclusion: The results suggest that the vehicle of transmission was contaminated drinking water. Residents of affected area were advised to temporarily boil tap water. Because of continuous problems with water from the distribution system, building a new one from other water sources was considered.

Key words: outbreaks, norovirus, rotavirus, epidemiology, drinking water

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Izveček

Uvod: V marcu in aprilu 2010 je v Mengšu na območju s 3.000 prebivalci zaradi kontaminacije pitne vode prišlo do izbruha akutnega gastroenteritisa. Cilj naše preiskave je bil oceniti obseg izbruha, identificirati povzročitelje in preveriti hipotezo, da je bila pot prenosa v izbruhu pitje neprekuhane vode iz vodovoda, ter če bi bilo potrebno, predlagati ustrezne ukrepe.

Metode: Izvedena je bila retrospektivna kohortna raziskava, v katero je bilo vključenih 160 naključno izbranih gospodinjstev (z 20 % prebivalcev s prizadetega področja). Primer je bil prebivalec Mengša, ki se mu je pojavila driska, bruhanje ali bolečine v trebuhu.

Rezultati: Celotna stopnja zbolevanja je bila 31,3-odstotna. Na epidemijski krivulji je bilo vidno jasno kopičenje števila primerov, kar je nakazovalo izpostavljenost skupnemu viru okužbe. Prebivalci, ki so uživali neprekuhano vodo iz pipe, so imeli 4,8-krat (95% IZ: 0,7–32,7) večjo verjetnost, da zbolijo, kot neizpostavljeni. Pitje neprekuhane vode iz pipe, umivanje zob in uživanje surovega sadja in zelenjave, oprane z neprekuhano vodo iz pipe, je bilo povezano z gastroenteritisom (RR 3,1 (95%; IZ: 1,5–6,5), 3,1 (95% IZ: 1,2–8,1) in 2,3 (95% IZ: 1,2–4,3)). Ugotovljena je bila

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povezava med količino popite neprekuhane vode iz pipe in stopnjo zbolevanja med prebivalci. Norovirusi in rotavirusi so bili odkriti v vzorcih pitne vode in tudi v vzorcih blata zbolelih.

Zaključek: Naši rezultati kažejo, da je bila pot prenosa kontaminirana pitna voda. Prebivalcem prizadetega območja je bilo svetovano začasno prekuhavanje pitne vode. Zaradi stalnih problemov z vodo iz vodovoda se je začela obravnavati gradnja novega iz drugih vodnih virov.

Ključne besede: izbruhi, norovirus, rotavirus, epidemiologija, pitna voda

1 INTRODUCTION

Microbiologically contaminated drinking water has the potential to cause extensive outbreaks of illness due to the size of populations served by distribution systems and the large numbers of people who use certain recreational water facilities (1, 2, 3). Outbreaks of disease attributable to drinking water are not common in developed countries, but they do still occur and can lead to serious acute, chronic or sometimes fatal health consequences, particularly in sensitive and immunocompromised populations (4). The point of entry of the microbiological contamination of drinking water is usually located in the distribution network, like waste water backflows or contamination induced by maintenance work and at the water collection facilities (5, 6). Two criteria must be met for an event to be defined as a waterborne outbreak. First, two or more persons must be epidemiologically linked by the location of exposure to water, by time and by the characteristics of illness. Second, the epidemiologic evidence must implicate water as the probable source of the illness (7). In the last 6 years (2004-2009), a total of six waterborne outbreaks were reported in Slovenia, with 7 to 170 cases in each. The vehicle of transmission in the majority of them was microbiological contaminated drinking water at the water source or in the distribution system. In 4 outbreaks, the etiological agents could be identified. The identified etiological agents were Norovirus, *Cryptosporidium parvum* and *E. coli* (8).

On 2nd April 2010, the regional Public Health Institute of Ljubljana was informed about an outbreak of acute gastroenteritis in the town of Mengeš. They were also informed that, on the two previous days, the drinking water in part of the city had been contaminated during maintenance work at the water distribution system, affecting approximately 3000 residents, all served by water distribution system A. Forty-seven residents had fallen ill and had sought medical attention at local physicians and 10 had been directed to the Clinic for infectious diseases in Ljubljana. In 2009, the municipality of Mengeš (7396 inhabitants including the town of Mengeš) reported 41 cases of acute gastroenteritis of infectious aetiology (0-6 cases per month) to the regional Public Health Institute of Ljubljana (9).

The same day, the regional Public Health Institute of Ljubljana, in cooperation with the National Institute of Public Health, started an investigation to assess the extent of the outbreak, confirm the vehicle of transmission and initiate appropriate control measures.

2 MATERIALS AND METHODS

2.1 Reporting Patients with Acute Gastroenteritis

Local physicians in the area and at the Clinic for infectious diseases in Ljubljana were aware of the clinic outbreak and reported patients with acute gastroenteritis to the regional Public Health Institute of Ljubljana. According to the Law on communicable diseases, all cases of acute gastroenteritis and all outbreaks of communicable diseases in Slovenia must be reported to the regional Public Health Institutes.

2.2 Analytical Study

We conducted a retrospective cohort study. Our aim was to estimate the magnitude of the event and test the hypothesis that drinking unboiled water from the distribution system (tap water) on 31st March and 1st April was the potential vehicle for the outbreak. We defined a case for the purpose of our study as a resident of Mengeš (living in the area of the water distribution system A) who developed one of the following symptoms: diarrhoea (three or more loose stools within 24 hours), vomiting or abdominal pain between 31st March and 7th April 2010.

We collected the information for the study by mailed questionnaires. The water supply company provided a map of the city with a detailed indication of the area of water distribution system A. Since the company was not able to provide the addresses or phone numbers of all the households, we randomly selected 160 households from the residents of the affected area listed in the telephone directory. Four questionnaires were posted to each household (altogether 640 questionnaires, covering >20% of the 3000 affected residents), asking each member of the household to fill in the individual questionnaire. Questions covered demographic data, information about signs and symptoms of the disease,

epidemiological data on the type of water used for drinking at home with an emphasis on exposure to unboiled tap water, the volume of unboiled tap water drunk and the exposure to unboiled tap water according to use.

The collected data was entered into and analysed with EpiInfo v.3.5.1. Specific attack rates (AR), relative risks (RR) and 95% confidence intervals (95% CI) were calculated for consumption of different types of drinking water at home and for exposure to tap water from different sources. We also examined the dose-response relationship between the attack rate and the reported volume of unboiled tap water consumed.

2.3 Laboratory Investigations of Reported Patients

Local physicians and the Clinic for infectious diseases in Ljubljana collected stool clinic samples from patients with acute gastroenteritis. Those samples were tested for gastrointestinal bacteria and viruses.

2. 4 Environmental Investigations

Mengeš is a small town with approximately 5000 inhabitants close (15 km) to the Slovenian capital city of Ljubljana. The residents of the city are supplied by two different water distribution systems. Drinking water is treated with chlorine at the source. According to the regulation covering the quality of drinking water in Slovenia, the water distribution companies are obliged to perform internal control according to the HACCP system.

The water supply company in charge of the affected water distribution system A conducted a risk assessment of the distribution system. Additionally from 31st March

to 4th April 2010, the water supply company daily performed systematic sampling of the drinking water from the water distribution system in the affected area for laboratory testing. Samples of drinking water were tested for *E. coli*, coliform bacteria, enterococi, *Clostridium perfringens* and a colony count at 22 and 37°C according to the regulation covering the quality of the drinking water in Slovenia. They were also tested for viruses (10).

3 RESULTS

3.1 Reporting Patients with Acute Gastroenteritis

Until 11th April 2010, 52 patients with acute gastroenteritis that could be connected to the outbreak were reported by local physicians and the clinic for infectious diseases in Ljubljana to the regional Clinic Public Health Institute of Ljubljana. All the reported patients developed symptoms between 31st March and 7th April 2010. Three of the reported patients were hospitalized, no one died.

3.2 Analytical Study

By 10th May 2010, we had received questionnaires from 208 residents (approximately 7% of all the residents in the affected area) living in 74 households (response rate 46.2%). A median of 4.0 persons were living in the participating households (range 1 to 9). A total of 106/195 (54.3%) respondents were female. The median age of the respondents was 45.5 years (range 3-80 years) (Table 1).

Eighty-five respondents reported symptoms between the 31st of March and the 7th of April. Of these, 65 fulfilled the case definition.

Table 1. The demographic characteristics of the cohort and cases with attack rates (AR) and risk ratios (RR). Outbreak of acute gastroenteritis in Mengeš, March-April 2010.

Tabela 1. Demografske znančilnosti kohorte in primerov s stopnjami zbolevanja (AR) in razmerji tveganj (RR). Izbruh akutnega gastroenteritisa Mengeš, marec-april 2010.

	All / Vsi	Cases / Primeri	AR (%)	RR (95% CI)
All / Vsi	208	65	31.3	
Sex / Spol				
Female / ženske	106	33	31.1	1.0
Male/ moški	89	28	31.5	1.0 (0.7-1.5)
Age group / starostna skupina				
0-14	12	3	25.0	1.3 (0.4-4.4)
15-44	88	31	35.2	1.6 (0.7-3.6)
45-64	74	24	32.4	1.5 (0.7-3.5)
65+	32	6	18.7	1.0

Fifty-eight (89.2%) cases reported the exact dates of illness (Figure 1). The first cases appeared on 31st March 2010 and their number peaked on 1st April 2010 and declined in the following days. The onset of symptoms for 90% of the cases was between 31st March and 3rd April 2010.

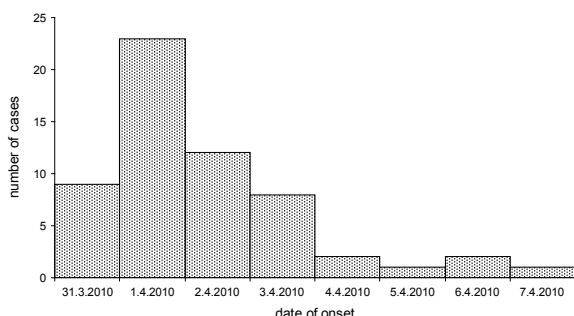


Figure 1. Date of onset of the illness among cases (n=58). Outbreak of acute gastroenteritis in Mengeš, March-April 2010.

Slika 1. Datum začetka obolenja med primeri (n=58). Izbruh akutnega gastroenteritisa Mengeš, marec-april 2010.

Table 2 shows the symptoms and signs of illness reported by cases. The duration of illness ranged from 2 hours to 18 days, with a median of 1-2 days. Ten cases (15.8%) sought medical advice and one case was hospitalized; none died.

Table 2. The symptoms and signs of illness reported by cases (n=65). Outbreak of acute gastroenteritis in Mengeš, March-April 2010.

Tabela 2. Simptomi in znaki obolenja med primeri (n=65). Izbruh akutnega gastroenteritisa Mengeš, marec-april 2010.

Symptoms and signs / Simptomi in znaki	Number / Število	%
Diarrhoea / driska	39	60.0
Vomiting / bruhanje	22	33.8
Fever (>38°C) / temperatura	8	12.3
Abdominal pain / bolečine v trebuhu	47	72.3
Headache / glavobol	17	26.2
Feeling ill / slabo počutje	41	64.1
Nausea / slabost	32	49.2

All but two respondents reported on the type of water they used at home for drinking between 31st March and 1st of April 2010 (Table 3). Residents who reported drinking unboiled tap water at home had the highest attack rate (43.4%) and were 4.8 times (95% CI 0.7-32.7) more likely to become ill than residents who had not drunk any type of water (AR=6.6%).

The specific attack rates, relative risks and percentage of cases exposed to unboiled tap water according to different use at home on 31st March and 1st of April 2010, when the water in distribution system was contaminated, are given in Table 4.

Table 3. The type of water used for drinking at home on 31st March and 1st April 2010 with attack rates (AR) and risk ratios (RR). Outbreak of acute gastroenteritis in Mengeš, March-April 2010.

Tabela 3. Vrsta vode, ki so jo uporabljali za pitje doma 31. marca in 1. aprila, s stopnjami zbolevanja (AR) in razmerij tveganj (RR). Izbruh akutnega gastroenteritisa Mengeš, marec-april 2010.

type of drinking water / vrsta pitne vode	All / Vsi	Cases / Primeri	AR (%)	RR (95% CI)
unboiled tap water / neprekuhana pitna voda	122	53	43.4	4.8 (0.7-32.7)
boiled tap water / prekuhana pitna voda	10	2	20.0	2.7 (0.3-26.1)
bottled water / ustekleničena voda	59	9	15.2	2.1 (0.3-15.5)
no water / brez vode	15	1	6.6	ref.

Table 4. The specific attack rates (AR), relative risks (RR), 95% confidence intervals (95% CI) and the percent of cases exposed to unboiled tap water according to use. Outbreak of acute gastroenteritis in Mengeš, March-April 2010.

Tabela 4. Specifične stopnje zbolevanja (AR), razmerja tveganj (RR), 95 % intervali zaupanja (95 % IZ) in delež izpostavljenih primerov neprekuhani pitni vodi glede na uporabo. Izbruh akutnega gastroenteritisa Mengeš, marec-april 2010.

	Exposed/ Izpostavljeni			Not exposed/ Neizpostavljeni			RR	95% C.I.	% cases exposed/ % izpostavljenih primerov
	Cases/ Primeri	Total/ Skupaj	AR%	Cases/ Primeri	Total/ Skupaj	AR%			
using unboiled tap water for drinking / pitje neprekuhane pitne vode	52	120	43.3	7	65	10.8	3.1	1.5-6.5	80.0
using unboiled tap water for brushing teeth / uporaba neprekuhane pitne vode za umivanje zob	60	162	37.0	4	42	9.5	3.1	1.2-8.1	92.3
eating raw fruit and vegetables washed with unboiled tap water / uporaba neprekuhane pitne vode za umivanje sadja in zelenjave	51	127	40.1	9	62	14.5	2.3	1.2-4.3	78.5

Cases in contact with unboiled tap water from different sources at home had higher attack rates than non-cases: using unboiled tap water for drinking (RR 3.1), using unboiled tap water for brushing teeth (RR 3.1) and eating raw fruit and vegetables washed with unboiled tap water (RR 2.3).

A total of 202 (97.1%) residents reported on the volume of unboiled tap water they drank at home on the 31st of March and the 1st of April when water in distribution system was contaminated. The results are shown in Figure 2.

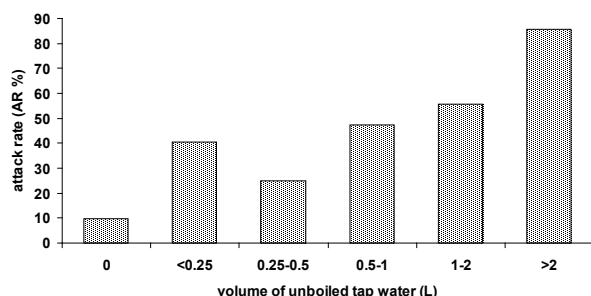


Figure 2. Attack rates (AR) according to the volume of unboiled tap water drunk (n=202). Outbreak of acute gastroenteritis in Mengeš, March-April 2010.

Slika 2. Stopnje zbolevanja (AR) glede na volumen popite neprekuhane pitne vode (n=202). Izbruh akutnega gastroenteritisa Mengeš, marec-april 2010.

Residents who drank a larger volume of unboiled tap water had higher attack rates than residents who had not consumed unboiled tap water at home.

3.3 Laboratory Investigations of Reported Patients

Laboratory analysis of stool samples was conducted for three of the 52 patients with acute gastroenteritis (6%) reported by physicians. Samples were positive for viruses with real time PCR (two for Rotavirus and Norovirus and one for Norovirus).

3.4 Environmental Investigations

The city of Mengeš is supplied by two different permanent water distribution systems. The outbreak occurred in the part of the city supplied by the water distribution system with the water source of Kravec (the area supplying water to distribution system A). This water distribution system also supplies drinking water for two neighbouring municipalities. The first part supplies the municipality of Komenda and the second part the municipality of Mengeš (including part of the city of Mengeš, the area with water distribution A with approximately 3000 residents). The two municipalities have their own separate water distribution companies in charge of their part of the distribution system.

From 24th to 31st March 2010, the area served by water distribution system A was connected to a temporary water distribution system, because routine maintenance

works were being performed by the water distribution company from the municipality of Komenda on the pipes of the permanent water distribution system (with the water source of Krvavec) on the border between the two municipalities. It was later discovered that, during the replacement of a water pipe, the water distribution system was damaged and, at one point, water from the sewage system contaminated the water in the drinking water distribution system. On 31st March 2010, the work was over and the area served by water distribution system A was connected back to the permanent water distribution system. On that same day, the water company from the municipality of Mengeš detected that drinking water in the distribution system was contaminated and took several measures to clean up the affected system.

The degree of contamination of the water from distribution system was followed up daily. All the water samples from the affected distribution system in the area of water distribution A taken on 31st March 2010 showed faecal contamination. The results were elevated above the allowed values for *E. coli*, coliform bacteria, enterococci and *Clostridium perfringens*. Rotavirus and Norovirus were also detected in the water samples from the affected area.

The water samples taken late on 1st April 2010 were already in the range of the allowed values according to the regulations covering the quality of the drinking water in Slovenia.

3. 5 Recommendations and Actions

From 31st March to 4th April 2010, the following public health measures were in place (implemented by the water supply company in cooperation with the Regional Public Health Institute) in the affected area of Mengeš concerning drinking water from the water distribution system:

- Inhabitants were advised through the local media to boil drinking water from the local distribution system,
- Inhabitants were advised to use only boiled water for cooking, washing fruit and vegetables and brushing teeth,
- The distribution of uncontaminated drinking water (bottled water and water from water tanks) to the local kindergarten and elementary school and elementary school was organised.

Several measures were taken to clean up the water distribution system in the area by the water supply company (cleaning, washing off and disinfection). The degree of contamination was followed up daily since 31st March by sampling the water from the water distribution

system. On the 4th of April, after two consecutive samples of water from the distribution system were negative, the water was declared suitable for drinking.

4 DISCUSSION

The primary objectives of our investigation were to assess the extent of the outbreak, identify the vehicle of transmission and, if necessary, initiate appropriate control measures. The number of cases identified in the retrospective cohort study was higher than the number of patients with acute gastroenteritis reported by physicians. Our data supports our hypothesis that the vehicle of the outbreak was contaminated drinking water from the water distribution system on the 31st March and 1st of April 2010. Because the residents consuming unboiled tap water were more likely to become ill than the non-exposed, there was a dose-response relationship between the volume of unboiled tap water consumed and the attack rate among residents and the epidemic curve showed a clear peak in the number of cases (suggesting a point source). The pathogens identified in the water samples and in the stool samples of cases were Norovirus and Rotavirus.

Some limitations apply to our results. All epidemiological data was collected by questionnaires posted by mail and could not be verified. We assume that there was also some information bias, that people showing symptoms replied more because the outbreak gained a lot of attention in the local media. The case definition used in the retrospective cohort study was quite broad and based only on clinical criteria, so it is possible that some cases fulfilling our case definition could be attributed to infection by a different source or to certain other medical conditions. We were not able to calculate a classical response rate as in other studies because the exact number of inhabitants of each household was not available before the study. Therefore, each household received four questionnaires. The response rate in the retrospective cohort study was not very high; 46% households responded. There is also some possibility of a selection bias since ill people were more likely to respond than not-ill.

The number of patients with acute gastroenteritis reported by physicians underestimates the real extent of the outbreak. 52 cases of acute gastroenteritis were reported. However, through the retrospective cohort study, we were able to identify 65 cases fulfilling our case definition with an overall attack rate of 31.3%. We assume that many cases did not seek medical attention because the symptoms of the illness were mild and short-lasting, and there was also the continuous

problem of the general underreporting of communicable diseases by physicians in Slovenia. Similar findings had already been described before in another waterborne outbreak investigation that took place in Slovenia in Piran in 2008 (11).

The epidemic curve showed a clear peak in the number of reported cases on 1st April 2010 and a decline over the following days, which is suggestive of a common source exposure. Drinking unboiled water from the water distribution system was positively associated with being ill and this association was stronger than for other types of drinking water. We were also able to demonstrate a dose-response relationship between the volume of unboiled tap water consumed and the attack rate. The detection of Norovirus and Rotavirus in the stool samples of the cases reported by physicians supports the results of our study, because those pathogens have been already detected in cases of other waterborne outbreaks (12, 13). In our outbreak, more than one different pathogen was isolated from the stool samples of patients. This is common in outbreaks caused by the contamination of drinking water by sewage water (14, 15). It is indeed biologically plausible that the vehicle for the outbreak caused by Norovirus and Rotavirus is the drinking water (16). Besides the multiple pathogens identified, we were able to demonstrate high attack rates, while the epidemic curve was suggestive of a common point source, which is compatible with findings in other waterborne outbreaks described before (17, 18, 19). Thus, these results, combined with the events, brought to light during the environmental investigation, strongly suggest that the vehicle of the outbreak was the contaminated drinking water from the water distribution system. The environmental investigations further support our epidemiological findings; beside other pathogens, Norovirus and Rotavirus were also detected in water samples from the contaminated water distribution system.

To our knowledge, this is a first published description of a waterborne outbreak investigation in Slovenia with strong epidemiologic evidence from an analytical study implicating drinking water as the probable source of the illness and with Norovirus and Rotavirus identified as causative agents.

Waterborne outbreaks have been shown to result from several concurrent faulty factors. To ensure good drinking water risk management, critical barriers such as water treatment, source protection, distribution security and monitoring/response capabilities are needed (20). The risk assessment of the water distribution system showed that the point of entry of the contamination of drinking water was located in the distribution system,

not at the water collection facility and was caused by maintenance work when the pipe of the water distribution system was damaged and water from the sewage system contaminated the drinking water in the distribution system. Leakages in the distribution system pose an increased risk of gastrointestinal illness for people consuming drinking water from the system (21).

5 CONCLUSIONS

The results of our investigation showed that this outbreak was caused by contaminated drinking water from the water distribution system. It was discovered that the pipes were damaged during routine maintenance work on the water distribution system and this caused the contamination of the drinking water. Also in the past, there have been continuous problems with the water source of Kravvec and with the water distribution system, which is old. There have been insufficient supplies of drinking water, especially in the dry summer months, and the water at the source was often not clear. To solve those problems, the City Council of Mengeš was considering the possibility of building a new water distribution system after this outbreak using more recent techniques and other water sources.

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