An Outbreak of Waterborne Giardiasis Associated with Heavy Water Runoff Due to Warm Weather and Volcanic Ashfall

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Abstract: From mid-June through early August 1980, an outbreak of gastrointestinal illness in Red Lodge, Montana affected approximately 780 persons, as estimated from attack rates of 33 per cent and 15 per cent in urban and rural residents, respectively. *Giardia lamblia* was identified in stool specimens from 51 per cent of 47 persons with a history of untreated gastrointestinal illness and in 13 per cent of 24 specimens from asymptomatic persons ($p = .00045$, Fisher's Exact Test).

The epidemic curve was bimodal with peaks in mid-June and mid-July. Each peak occurred about three weeks after an episode of very heavy water runoff resulting from warm sunny weather and snow darkened by ashfall from the Mt. St. Helens volcanic eruption of May 18, 1980. Unfiltered and inadequately chlorinated surface water was supplied by the city water system, which was implicated as the vehicle of transmission in the outbreak. Water systems providing unfiltered surface water are more likely to become contaminated during periods of heavy water runoff. (*Am J Public Health* 1983; 73:868–872.)

Introduction

Investigations of epidemic giardiasis have implicated public water systems that fail to adequately treat surface water as the cause of community-wide infections.[1-7] We report here the results of an investigation in 1980 of an outbreak of giardiasis transmitted during a period of heavy water runoff by a small community water system that provided unfiltered surface water.

Background

In July 1980, the Montana Department of Health and Environmental Sciences was notified that several hundred cases of acute gastrointestinal illness had occurred in the city of Red Lodge, in south central Montana. The outbreak appeared to have begun in June and to have affected primarily residents within the city limits.

The Red Lodge population was distributed in two definable areas: 1,873 persons resided within the compact city limits, while 1,087 persons lived in rural areas within 10 km of Red Lodge.[8] The main source of the city's water was West Fork Rock Creek, which drained surface runoff from snow in the watershed of the Absaroka Range of the Rocky Mountains west of Red Lodge. The water system served an area that coincided almost exactly with the city limits.

Address reprint requests to Dr. Juranek, Division of Parasitic Diseases, Centers for Disease Control (CDC), Atlanta, GA 30333. The investigation reported here was performed while Dr. Weniger was with the Division of Parasitic Diseases, CDC; he is now in the Field Services Division, Epidemiology Program Office, CDC, assigned as medical epidemiologist to the Health Division of the Oregon State Department of Human Resources, Portland. Dr. Blaser, Assistant Professor of Medicine at the University of Colorado School of Medicine and Veterans Administration Hospital, Denver, was with the Bacterial Diseases Division, CDC, during the investigation; Ms. Gedrose is Nurse Consultant, Health Services Division, Montana State Department of Health and Environmental Sciences, Helena; Mr. Lippy is a sanitary engineer with the Health Effects Research Laboratory, Environmental Protection Agency, Cincinnati, Ohio; and Dr. Juranek is Deputy Chief, Protozoal Diseases Branch, Division of Parasitic Diseases, CDC, Atlanta. This paper, submitted to the Journal July 23, 1982, was revised and accepted for publication September 29, 1982.

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Materials and Methods

Prescription Study

Records of prescriptions written by the three physicians in the area were examined at the two pharmacies in town. The nearest alternative source of prescriptions was 42 km away. Persons receiving one or more antidiarrheal prescriptions* from June 15 through August 5 were matched to persons buying other prescriptions (controls) in the same period of time, and their place of residence was determined. We plotted on a city map the places of residence of persons who purchased antidiarrheal prescriptions.

Random Telephone Survey

On August 7, 1980, a questionnaire was administered by telephone to households in the Red Lodge area. Because waterborne transmission of the disease was suspected, approximately equal numbers of two groups were randomly chosen for sampling—one from within the city limits, virtually all of whose homes are served by the city water system, and the other from rural residents, most of whom use well or spring water.**

Using volunteer surveyors, 73 per cent (98 of 135) of the selected city households and 60 per cent (74 of 124) of the selected rural households were contacted by telephone. Four households refused to participate. Data were collected for 390 household members from the 168 responding households.

A case of gastrointestinal (GI) illness was defined as a survey respondent reporting one or more days of diarrhea (three or more liquid stools per day) or at least three of the following symptoms: nausea, vomiting, stomach cramps, "bloating or gassy feeling in the stomach," or fever.

Stool Examination and Culture

Single stool specimens were obtained from 61 symptomatic persons at varying times after onset of illness and from

*The prescription drugs examined were metronidazole (Flagyl), quinacrine (Atabrine), furazolidone (Furoxone), diphenoxylate/atropine (Lomotil, Lonox), loperamide (Imodium), and bismuth/paregoric. Use of trade names is for identification only and does not constitute endorsement by the Public Health Service or the US Department of Health and Human Services.

**To create a stratified random sample with approximately equal numbers of people on each type of water source, we used the alphabetical telephone directory to choose every 7th listing of city telephone subscribers and every 3rd listing of rural telephone subscribers.

24 persons with no history of gastrointestinal symptoms in the previous two months. Specimens were collected from ill persons attending the local clinic and from well and ill members of the general public, notified of the collection by newspaper advertisement. Stools were preserved in 5 per cent formalin and in PVA-fixative[9] for parasitologic examination and inoculated into Carey-Blair medium for bacteriologic culture. Specimens for virus isolation were not collected. Using standard methods[10] at the Centers for Disease Control (CDC), all specimens in formalin were examined microscopically for enteric parasites by direct wet mount and after formalin-ether concentration,[11] if the direct examination was negative. For stools from both well and ill persons that were negative for *Giardia* after the above procedures, the PVA-fixed specimen was examined microscopically after permanent Wheatley-trichrome staining.[12] Random specimens from 18 symptomatic persons were cultured for *Salmonella, Shigella, Campylobacter, Yersinia enterocolitica,* invasive and enterotoxigenic *Escherichia coli,* and pathogenic vibrios, using methods described elsewhere.[13-19]***

Evaluation of Water System and Weather

We evaluated the water system and interviewed local officials and residents. To locate a source of contamination, water samples were collected from West Fork Rock Creek upstream of the treatment plant, from a city well, and from tapwater in the city and were tested for coliforms and fecal coliforms using standard methods.[20] Residual free chlorine was measured in tapwater. Large-volume water samplers capable of filtering protozoal cysts such as *Giardia lamblia* from the water[21] were installed at the treatment plant. Records of daily measurements of turbidity on intake water at the plant were reviewed for the months of May through July for the years 1977 through 1980. Turbidity readings had been regularly recorded since May 27, 1977. Data from the National Weather Service for the Red Lodge area[22,23] were reviewed.

Results

Prescription Analysis

A significantly greater number of those persons buying antidiarrheal prescriptions (213 of 263, 81 per cent) lived in the city limits of the town, compared with those buying other types of prescriptions (150 of 262, 57 per cent; odds ratio = 3.2, $X^2 = 33.56$, $p < .001$). There was no apparent geographic clustering of persons within the city limits who purchased antidiarrheal prescriptions.

Random Telephone Survey

There were 94 cases of GI illness among the 390 survey respondents. The epidemic curve of these cases demonstrates two separate peaks of onset of illness, the first in mid-June and the second in mid-July (Figure 1).

Respondents whose homes were served by city water had an attack rate for GI illness of 33 per cent, compared with a 15 per cent rate for those who reported using springs, wells, or bottled water (Table 1). Respondents who did not use city water but worked in the town had an attack rate of 36 per cent, compared with 13 per cent for those who did not come into town to work. Those who did not use city water had attack rates directly related to their frequency of visiting town.

Of the 94 cases of GI illness detected in the survey, 11 reported having missed from one to 20 days of work because of their illness. There was a total of 44 person-days of work missed, averaging about one-half day of work missed per case.

There were no significant differences in age or in quantities of reported water consumption between city water and non-city water users, or between cases and those without GI illness. No significant association was found between illness and increasing consumption of city tapwater, drinking raw milk, owning a dog, exposure to a dog with diarrhea, prior attendance at a number of recent public events, or eating in restaurants. No significantly increased attack rate for the second wave of illness in July was found in members of households which had an ill person during the first wave in June.

By extrapolating from the sample, it can be estimated that approximately 781 local residents were affected by the illness (618 city residents and 163 rural residents).

Stool Examination

A significantly greater number (24 of 47, 51 per cent) of stool specimens from those who had been ill with gastrointestinal disease and had not yet been treated with any antidiarrheal medication were positive for *Giardia lamblia,* compared with specimens from volunteer stool donors who had had no diarrheal illness (3 of 24, 13 per cent; $p = .00045$, Fisher's exact test). Of specimens examined at the Montana State Laboratory, 22 of 69 (32 per cent) were positive for *G. lamblia.*

All 18 specimens cultured at the CDC were negative for bacterial pathogens. *Campylobacter jejuni* was isolated from one of the four specimens cultured at the Montana State Laboratory.

Water System

Water from West Fork Rock Creek flowed by gravity through a concrete flume to a headhouse, where it was screened of floating debris and passed into small basins for settling of heavy particles such as grit. Infiltration galleries adjacent to a recharge reservoir provided insufficient water flow and were not in use. At the headhouse water entered two mains, only one of which was being dosed from a fixed-rate injector device supplied by a single cylinder of chlorine gas. There was no filtration. The water traveled via the two mains in parallel to feed a common grid distribution network for the city. A well in the city supplemented the system when demand exceeded the surface water supply during dry periods. Tap water samples on August 3 and 4 revealed no chlorine residual in the city water. One of two tapwater samples taken in the city was positive for coliform and fecal coliform bacteria. A sample taken at the well was negative for coliforms. *Giardia* cysts could not be identified in either of two high-volume water sampling filters placed at the waterworks intake in early August.

In addition to national forest campgrounds and hiking trails, two small subdivisions of summer cottages and year-round homes were located in the watershed, 3 to 4km upstream of the city water intake and within 20m of the banks of West Fork Rock Creek. Although regulations required the use of incineration systems to avoid discharging sewage, some of the homes used septic tanks. Water sam-

***In addition to the specimens examined at CDC, 69 stool specimens for parasitologic examination and four stool specimens for bacterial culture from Red Lodge area residents were received from July through October 1980 at the Laboratory Division of the Montana Department of Health and Environmental Sciences.

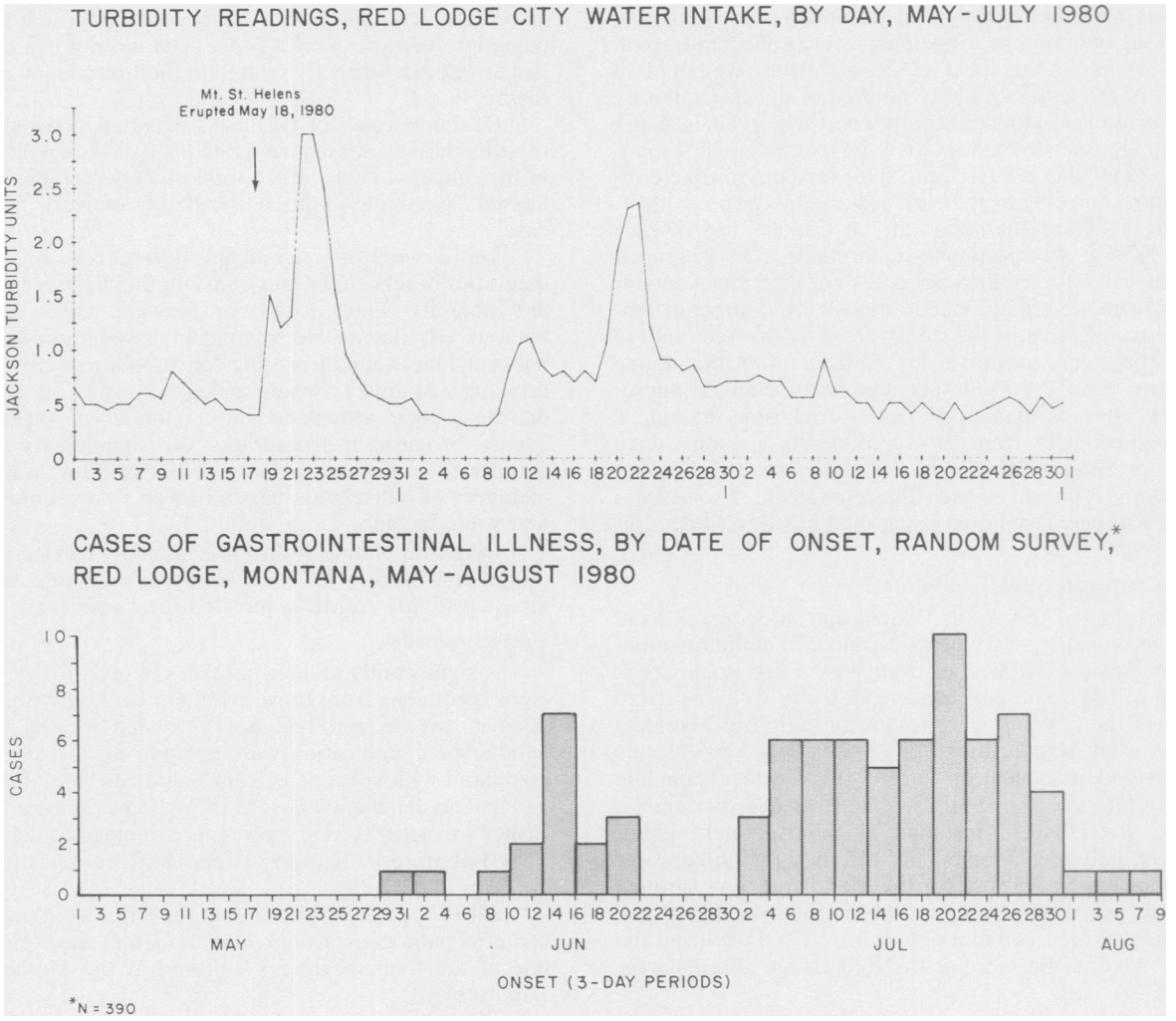

FIGURE 1

ples taken upstream and downstream of the subdivision yielded low concentrations (≤5/100ml) of coliforms and fecal coliforms. Fecal droppings indicated that cattle had recently grazed alongside the creek within 50m upstream of the water intake. Fish and game personnel reported that beaver inhabited the watershed.

Weather

Two episodes of heavy spring runoff from melting snow occurred in 1980. Both took place after the Mt. St. Helens volcano erupted 1000km to the west in the state of Washington on May 18, 1980. Fallout from the volcano reached Red Lodge on May 19 and covered the town and snowfields in the adjacent mountains with a layer of dark volcanic ash. The first heavy runoff occurred from May 20 to 22, causing flooding and washing out roads and bridges in the area.[24] The second occurred from June 20 to 22. The weather at the time of each runoff was unusually sunny and warm. The recorded maximum temperatures from May 20 to 22 were 23.9°, 26.1°, and 28.9°C, respectively, and 25.6°, 25.6°, and 27.8°C from June 20 to 22, respectively.[22] These temperatures greatly exceeded the 30-year average daily maximum temperatures for Red Lodge for the months of May (16°C) and June (19.9°C).[23]

Red Lodge residents reported increased cloudiness in city tapwater during the two periods of heavy water runoff. This was reflected as an increase in turbidity measured at the treatment plant, which occurred in a bimodal pattern and was appreciably higher than that seen in comparable periods in previous years. When the water turbidity measurements of 1980 are superimposed on the epidemic curve of illness from the random telephone survey, there is a similarity in the shape of the bimodal curves and an interval of about three weeks between the peak of turbidity and the peak of illness (Figure 1).

Discussion

Although *Giardia* cysts could not be filtered from city water sampled six weeks after contamination probably occurred, the epidemiologic investigation implicated the city water supply as the vehicle of transmission in this outbreak. Using the estimate of approximately 780 local cases (plus an unknown number of cases among visitors), this outbreak would rank among other large outbreaks of suspected or confirmed waterborne giardiasis reported in the United States since 1954.[2–4,6,7,25–31]

The bimodal increase in water turbidity corresponded to

TABLE 1—Random Survey of Risk Factors for Gastrointestinal Illness

	GI Illness		Per Cent Attack Rate	Relative Risk	X^2	P
	Yes	No				
All respondents by source of water						
City water	66	134	33	2.2	15.00	<.001
Non-city water	28	154	15			
Users of non-city water by employment in town						
Yes	9	16	36	2.8	6.02	<.02
No	17	110	13			
Users of non-city water by frequency of visiting town						
Visits per month						
0	8	62	11		9.99*	<.05
1–3	2	32	6	.5		
4–6	5	29	15	1.3		
7+	13	31	30	2.6		

*Contingency table X^2

the bimodal epidemic curve of illness, suggesting that the water may have been contaminated and infective only during two very short periods. The epidemic peaks would probably not have been separate if contamination had been more continuous. The three-week intervals between the peak of water turbidity and the peak of illness may represent an averaged incubation period for the illness in the population. Incubation periods of about 15 days have been reported for giardiasis in travelers returning from the Soviet Union[32,33]; a longer mean incubation period may result from a smaller infecting dose.

The unusual combination of warm sunny days and the increased absorption of heat by the darkened ash-covered snowfields of the watershed were likely to have triggered the unusually heavy water runoff that probably led to contamination of the city water system. During the outbreak, the city drinking water had been unfiltered, marginally chlorinated surface water from an unprotected watershed with several possible sources of contamination, such as overflow from septic tanks, and the presence of hikers, campers, and wildlife. Beavers, dogs, and cattle, as well as other animals that probably inhabit the Red Lodge watershed, may be infected with *G. lamblia*, and act as a reservoir of the disease.[4,34]

Control measures implemented in this outbreak included the recommendation for the public to temporarily boil drinking water, the rearrangement of valves at the water plant to expose water in both mains to chlorine, and steps to increase residual chlorine levels to mg/liter (1 ppm) for one hour contact time to achieve a cysticidal dosage. Several months after the outbreak, new chlorination equipment was installed to inject chlorine in proportion to water output and to automatically switch to a reserve tank when the active chlorine cylinder empties. Nevertheless, the chlorine dosages commonly used in water treatment—<0.5 mg/liter—and even 1.0 mg/liter may not be cysticidal to *Giardia lamblia* under all conditions of pH, temperature, turbidity, and contact time that may occur.[35–37] Prevention of future outbreaks of giardiasis would best be achieved by installation and proper maintenance of filtration equipment capable of removing cysts of protozoal parasites such as *Giardia*.[38,39]

In late 1982 the city discontinued using surface water from West Ford Rock Creek and began providing well water pumped to a new holding reservoir. Water meters were installed to encourage conservation of the limited supply of well water. Because this source is not considered sufficient for fire-fighting or the future growth of the town, planning is underway to build a filtration system for the more plentiful surface water from West Fork Rock Creek.

Water systems similar to the one involved in this outbreak using unfiltered surface water appear more likely to become contaminated during periods of heavy runoff. In the United States in 1980, there were over 4,000 public water supply systems serving a population of over 42,000,000 persons which were reported to provide surface water without treatment by filtration.‡ The equipment and operation of many of these systems—predominantly small plants in rural areas—resemble the Red Lodge system during the outbreak. Operators of such systems in areas where *Giardia* contamination may occur should be aware of the risk during heavy runoff, at which time the public might be advised to boil tapwater or use an approved alternative source of drinking water.

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ADDENDUM

As a result of this outbreak, the City of Red Lodge obtained loans and grants from the Department of Housing and Urban Development and the Farmers Home Administration to build a $2.6 million water treatment plant, which will perform flocculation, filtration, and disinfection of surface water from West Fork Rock Creek. Construction has begun and completion is expected by late 1983.