Cryptosporidiosis in Georgia

A Classroom Case Study

INSTRUCTOR'S VERSION

Original investigators: Edward B. Hayes, MD[1]; Thomas D. Matte, MD, MPH[1]; Thomas R. O'Brien, MD, MPH[1]; Thomas W. McKinley, MPH[2]; Gary S. Logsdon, DSc, PE[3]; Joan B. Rose, PhD[4]; Beth L.P. Ungar, MD[5]; David M. Word, PE[6]; Paul F. Pinsky, MPH[1]; Michael L. Cummings, MD[1]; Margaret A. Wilson, MD, MPH[7]; Earl G. Long, PhD[1]; Eugene S. Hurwitz, MD[1]; and Dennis D. Juranek, DVM, MSc[1]

[1]Centers for Disease Control and Prevention, Atlanta, Georgia; [2]Georgia Department of Human Resources, Atlanta, Georgia; [3]Environmental Protection Agency, Cincinnati, Ohio; [4]University of Arizona, Tucson, Arizona; [5]Uniformed Services University of Health Sciences, Bethesda, Maryland; [6]Georgia Department of Natural Resources, Atlanta, Georgia; and [7]Morehouse School of Medicine, Atlanta, Georgia.

Case study and instructor's guide created by: Jeanette K. Stehr-Green, MD, Public Health Foundation, Washington, D.C., for the Division of Parasitic Diseases, National Center for Emerging and Zoonotic Infectious Diseases, Centers for Disease Control and Prevention.

Note: *This case study is based on a real-life outbreak investigation undertaken in Georgia in 1987.*[1] *Certain aspects of the original outbreak and investigation have been altered, however, to assist in meeting the desired teaching objectives and to allow completion of the case study within the allotted time.*

Students should be aware that this case study describes and promotes one particular approach to outbreak investigation; however, procedures and policies in outbreak investigation can vary by country, state, and outbreak.

The developers of this case study anticipate that the majority of outbreak investigations will be undertaken within the framework of an investigation team that includes persons with epidemiology, microbiology, and environmental health expertise. Through the collaborative efforts of this team, with each member playing a critical role, outbreak investigations are successfully completed.

Please send us your comments on this case study by visiting our Internet site at http://www.cdc.gov/epicasestudies. Include the name of the case study with your comments and be as specific as possible about the applicable location of comments or suggested edits.

September 2010

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
Atlanta, Georgia 30333

Target audience: This case study was developed for students and public health professionals interested in learning and practicing specific skills in outbreak investigation, especially outbreaks associated with drinking water. The target audience includes epidemiologists, environmental health specialists, sanitarians, public health nurses, disease investigators, health officers, and physicians.

Training prerequisites: Descriptive epidemiology, epidemic curves, measures of association, study design, and outbreak investigation. The student will also benefit from having familiarity with drinking water treatment processes and evaluation of a water treatment system but will likely rely on others with greater expertise in these areas in a real-life outbreak situation.

Teaching materials required: Graph paper, NORS Report_Cryptosporidiosis Outbreak in Georgia.pdf (completed form for the National Outbreak Reporting System [CDC 52.12]).

Time required: 3.5–4 hours.

Language: English

Level of case study: Basic ___ Intermediate _X_ Advanced __

Reviewed by:
Michael Beach, PhD, Centers for Disease Control and Prevention
Eric Mintz, MD, Centers for Disease Control and Prevention
Roderick Jones, MPH, Chicago Department of Public Health
Jonathan Yoder, MPH, MSW, Centers for Disease Control and Prevention
Daniele Lantagne, PE, Centers for Disease Control and Prevention
Sharon Roy, MD, MPH, Centers for Disease Control and Prevention
Joan Brunkard, PhD, Centers for Disease Control and Prevention
Joe Carpenter, PE, Centers for Disease Control and Prevention

Training materials funded by: Centers for Disease Control and Prevention (National Center for Emerging and Zoonotic Infectious Diseases and the National Center for Environmental Health).

INSTRUCTOR'S VERSION
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Learning Objectives:

After completing this case study, the student should be able to
1. discuss epidemiologic clues indicative of a waterborne disease outbreak as opposed to a foodborne disease outbreak;
2. describe a boil-water advisory and discuss problems that might be encountered in issuing such an advisory;
3. help plan a community survey to determine the prevalence and distribution of a health problem;
4. interpret a dose-response analysis for an exposure and development of a disease;
5. list activities that should be included in the evaluation of a public water system associated with an outbreak;
6. define turbidity and total coliform count and discuss how each are used to indicate drinking water quality;
7. discuss the typical steps used in the treatment of surface water at a community water treatment plant; and
8. describe the clinical features, epidemiology, and control of cryptosporidiosis.

PART I. OUTBREAK DETECTION

On January 21, a physician notified the Georgia Department of Human Resources (GDHR) of a dramatic increase in acute gastroenteritis among students at a college in Carrollton, Georgia. (Carrollton is a small town located in western Georgia [population estimate: 16,250] and is the county seat of Carroll County [population estimate: 64,900].)

The physician reported examining hundreds of students with a gastrointestinal illness at the college's infirmary during the previous week. The majority of students reported having abdominal pain and watery diarrhea of several days duration.

Typically, approximately 100 students were examined at the infirmary each day, the majority of whom presented with upper-respiratory infections or injuries. On January 20 alone, over 200 students were examined at the infirmary for gastroenteritis.

Question 1: Do you think these cases of gastrointestinal illness represent an outbreak at the college? Why or why not?

An outbreak is the occurrence of more cases of a disease than expected for a particular place and time. Normally approximately 100 students were examined each day at the college infirmary, only a minority of whom had gastrointestinal symptoms. During the previous week, the number of students with gastrointestinal illness increased dramatically, reaching over 200 on one day alone. Therefore, these cases of gastrointestinal illness probably represent an outbreak. What is unclear is whether the outbreak is limited to the college or if the wider community might also be affected.

Note: *The terms outbreak and epidemic are used interchangeably by the majority of epidemiologists. The term outbreak is sometimes preferred, particularly when talking with the press or the general public, because it is not as frightening as epidemic.*

The physician reported that stool specimens had been collected from selected ill students and had been submitted to the hospital laboratory for testing. Because the physician had an interest in parasitology, he had specifically requested that the stools also be examined for parasites.

The physician reported that cultures for bacterial pathogens had been negative. On microscopic examination, four specimens were determined to be positive for *Cryptosporidium*. The earliest known onset of illness among the *Cryptosporidium*-positive students was January 11.

Question 2: How is cryptosporidiosis transmitted? On what sources of infection should public health officials focus? (See Appendix A for additional information about cryptosporidiosis.)

Cryptosporidiosis is a protozoal parasite that is spread by the fecal-oral route, meaning it is shed in the stool of a host and enters the mouth of the next host by some means. Modes of transmission include waterborne, foodborne, person-to-person, and animal-to-person spread. The incubation period for cryptosporidiosis is 2−10 days, with an average of approximately 7 days.

Oocysts, the infectious stage of Cryptosporidium, appear in the stool of an infected person at the onset of symptoms and continue to be excreted for several weeks after symptoms resolve. Cryptosporidium oocysts are infectious immediately upon excretion from the body and can remain infectious, outside the body, for 2−6 months in a moist environment. Cryptosporidium is chlorine-resistant and can live for days in chlorine-treated water.

In investigating the source of the cryptosporidiosis cases at the college, public health officials need to keep an open mind as to the possible source. They should collect information pertinent to all possible modes of transmission (i.e., exposure to foods, water, and contact with infected humans or animals) and focus on the 2 weeks before onset of illness among patients.

Characteristics among patients can provide clues that indicate one mode of transmission over others. For example

- *person-to-person transmission − clustering of patients in social units (e.g., dorms or dorm rooms, sororities/fraternities, and classes); occurrence of cases in waves, separated by approximately one incubation period of the etiologic agent;*
- *transmission by a food − illness among persons who have shared a common meal or food and an onset of illness consistent with when the shared meal or food was consumed; an increased risk for illness among certain groups (i.e., those more likely to eat certain types of foods); a geographic distribution of cases similar to the geographic distribution of food products;*
- *transmission by public drinking water − a widespread illness affecting both sexes and all age groups; a geographic distribution of cases consistent with public water distribution but not food distribution patterns; a dose-response with increasing attack rates among persons consuming more water; concurrent complaints about water quality throughout the affected community; the involvement of multiple pathogens;*
- *transmission by contaminated private well water − cases clustered in areas adjacent to cattle ranches, farms, or other sites that are served by private wells; and*
- *transmission by recreational water − illness among persons who have shared a common recreational water exposure (e.g., a water park, community pool, or lake).*

Staff from GDHR contacted the Carroll County Health Department about the outbreak. Because the majority of the ill students lived on campus and participated in the university meal plan, concerns were voiced regarding possible foodborne transmission of the infection at the college. Within a few hours of the initial report, an environmental health specialist from the Carroll County Health Department was dispatched to the college to interview food service staff and to inspect the kitchen at the main cafeteria for food safety problems.

Meanwhile, staff from GDHR undertook steps to determine whether the cryptosporidiosis problem extended beyond the college.

Question 3: What existing sources of information might help determine if others in the community have cryptosporidiosis?

Multiple sources can help investigators identify additional cases of a disease under investigation (e.g., cryptosporidiosis) in a community. These sources will have varying degrees of specificity. Some can only identify increased illness in the community (e.g., absences), whereas others can identify persons with signs and symptoms indicative of the disease (e.g., watery diarrhea for cryptosporidiosis) or confirmed disease (e.g., confirmation of infection with Cryptosporidium).

Sources of additional cases include:

- *notifiable disease reporting (confirmed disease);*
- *reports by local or regional laboratories from examinations of stool specimens for Cryptosporidium (e.g., modified acid-fast stain and antibody-specific tests) (confirmed disease);*
- *emergency department patient logs (signs and symptoms);*
- *health maintenance organization logs of telephone calls regarding patient illnesses (signs and symptoms);*
- *chart reviews at hospitals or physician's offices (signs and symptoms and confirmed disease);*
- *requests to health care providers to report cases (signs and symptoms and confirmed disease);*
- *citizen complaints about possible foodborne or other illnesses to the health department (signs and symptoms);*
- *pharmacy reports of community usage of over-the-counter and prescription antidiarrheal medications (signs and symptoms);*
- *nursing homes and child care center records (signs and symptoms);*
- *employee or school absentee records (absences); and*
- *surveys of the population in question (signs and symptoms).*

Note: *In 1987, cryptosporidiosis was an uncommon diagnosis because of the limited ability to identify Cryptosporidium with standard ova and parasite testing and limited availability of more specific Cryptosporidium tests. Cryptosporidiosis was not a notifiable disease in the majority of states; therefore, identifying persons with undiagnosed watery diarrhea was the most likely recourse. Since that time, substantial efforts have been made to raise awareness of this disease in the medical community among both health care providers and laboratories and to increase specific testing for this pathogen. In 1994, the Council of State and Territorial Epidemiologists made cryptosporidiosis a nationally notifiable disease.*

A review of the patient intake log from the local hospital emergency department provided evidence of an increase in patients presenting with gastrointestinal illness starting the week of January 11. However, the majority of these patients were not students from the college. Calls to selected public schools and large businesses in Carroll County revealed widespread absenteeism. In addition, data from local pharmacies indicated an increase in sales of antidiarrheal medications throughout the county.

On the basis of these findings, staff from GDHR and the Carroll County Health Department concluded that the outbreak was not confined to the college but involved the entire Carroll County community. Reports from three communities bordering Carroll County indicated that those areas were not severely affected.

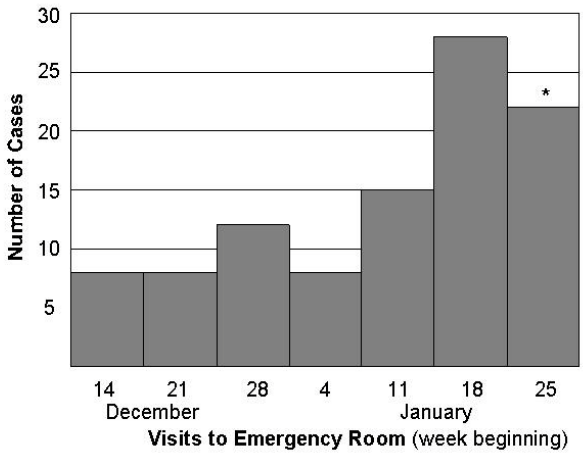
PART II. DESCRIPTIVE EPIDEMIOLOGY AND HYPOTHESIS GENERATION

To characterize the cryptosporidiosis cases and to seek clues about the source of the Carroll County outbreak, investigators from GDHR examined medical records from patients with acute gastroenteritis examined at the local hospital's emergency department.

During December 14 though January 25, a total of 98 patients were examined at the emergency department for acute gastroenteritis. The number of visits increased from 8−12 each week through the first week of January to 22−28 each week during the last 2 weeks of January (Figure 1).

Among the 65 patients with acute gastroenteritis examined at the emergency department since January 11, when the first *Cryptosporidium*-positive student had onset of illness, the following symptoms were reported: diarrhea (defined as three or more loose stools/day) (87%), stomach pain (80%), nausea (67%), vomiting (33%), fever (30%), and muscle aches (20%). Patients often reported that their diarrhea was watery. Approximately half of patients reported that their symptoms had been present for more than a week at the time they presented to the emergency department.

Figure 1. Numbers of visits by patients with acute gastroenteritis, local emergency department. Carroll County. Georgia by week of visit, December and January.



*Reporting for the week beginning January 25 was not complete

Patient's ages ranged from younger than a year to 76 years (mean: 34 years); 63% of patients were female. The majority of the patients lived within Carrollton's city limits as opposed to other parts of the county outside the city. Cases did not appear to cluster by neighborhood of residence, child care center, or school but were widely distributed around the city. Information on specific exposures was unavailable.

Stool specimens, available from 25 patients, were forwarded to the Centers for Disease Control and Prevention (CDC) for examination. *Cryptosporidium* was identified in 11 (44%) of the 25 specimens. One stool from a child aged 2 years was also positive for *Giardia*.

Question 4: Interpret the descriptive epidemiology of the outbreak including the epidemic curve (Figure 1). Were symptoms among patients consistent with cryptosporidiosis? Was clustering of cases apparent by selected demographic characteristics? What was the course of the outbreak and did it appear to be over?

The symptoms reported by patients presenting with acute gastroenteritis at the emergency department since January 11 were consistent with cryptosporidiosis. The majority of patients had diarrhea (often described as watery) and abdominal pain of more than a week's duration. Nausea, vomiting, and fever were less common.

The illness affected both sexes, although a disproportionate number of females were affected, and all age groups. It was more common within Carrollton than other parts of the county. These characteristics indicate a widespread exposure within the city (but not beyond it).

Cases began to increase the second full week of January, peaking the week of January 18. Because reporting for the week of January 25 was incomplete, whether cases were declining is difficult to determine. Given the incubation period of cryptosporidiosis (i.e., average of 7 days), exposures of interest probably occurred as early as the first week of January.

Because of the wide geographic distribution of cases within the Carrollton's city limits and the occurrence among all age groups, water was suspected as a possible source of the outbreak. Investigators reviewed public water system records and collected water specimens from multiple points in the water distribution system.

Routine total coliform counts from water samples collected from the public water system on January 5 were negative. In addition, samples of water collected from the college in Carrollton on January 22 and the public water system on January 23 were also negative for coliforms.

Question 5: What do total coliform counts indicate? What does a negative total coliform in treated water mean?

Coliform bacteria are nonpathogenic microorganisms located in the intestinal tracts of warm-blooded animals; in the soil; and on fruits, leaves, and grains. As a group, coliform bacteria are referred to as total coliforms.

A positive total coliform test (i.e., 1 or more coliform colony forming unit per 100 mL of water) indicates that the integrity of the water system has been compromised and that drinking water might have been contaminated. Because total coliforms are ubiquitous in the environment, however, a positive total coliform test might not indicate fecal contamination.

Therefore, if total coliforms are identified in a water sample, further analyses are warranted (e.g., testing for such other indicator microorganisms as E. coli, enterococci and bacteriophages) or for specific pathogenic microorganisms (e.g., norovirus). These other indicator or pathogenic microorganisms are more likely to be located in human feces or that of other mammals or birds and are, therefore, more specific indicators of fecal contamination than coliform bacteria.

Nonetheless, testing for total coliforms is still a valuable tool when investigating a possible waterborne disease outbreak because total coliforms include a greater variety of bacteria than the more specific indicators of fecal contamination and have a greater probability of detecting a breach in the integrity of the water system. In addition, testing for total coliforms is easier and less expensive than testing for other indicator or pathogenic microorganisms. Consequently, total coliform tests routinely are the first step in assessing the microbiological quality of water and the possible presence of pathogenic organisms.

Water treatment methods and environmental conditions can affect coliform bacteria and the agent causing an outbreak differently. For example, chlorinated sewage effluent might have no coliforms, but be laden with disease-causing agents not as susceptible to chlorine (e.g., viruses or parasites). Furthermore, if contamination was time-limited or affected only a part of the water distribution system, the sample collected might not reflect the condition of the water at the time it was ingested by those who became ill.

Investigators contacted the directors of the four nursing homes in the Carrollton area. The three nursing homes connected to the public water supply reported substantial numbers of residents with acute gastroenteritis. The nursing home that used a well for their water supply reported no residents with acute gastroenteritis.

On the basis of this information, the Carroll County Health Department issued a boil-water advisory on January 25.

Question 6: What is a boil-water advisory? How would you go about implementing one? What actions might improve the effectiveness of such an advisory?

A boil-water advisory is a public announcement that tap water should not be used for drinking and certain other purposes without additional treatment to prevent exposure to waterborne infectious agents and other health hazards. A boil-water advisory is usually announced by the water supply operator but is undertaken with the knowledge and support of the appropriate public health agency's officials because they can assist in developing the advisory, ensure that the correct information is distributed, and assist in informing the public and other special audiences.

A boil-water advisory should identify the purposes for which untreated tap water should not be used, actions (if any) that can be taken to make tap water safe (e.g., boiling), alternative sources of safe water, and actions that should be taken when a boil-water advisory is lifted. Sometimes a boil-water advisory will progress to a do-not-use or bottled-water advisory when tap water (even if treated) should not be used for any purpose (e.g., when a water system is being disinfected and can contain harmful levels of chlorine).

The majority of boil-water advisories include the following instructions (see Appendix B for details): Do not serve or consume

- *water that has not been disinfected,*
- *ice or drinks made with water that has not been disinfected, or*
- *raw foods rinsed with water that has not been disinfected.*

In addition, untreated tap water should not be used for hand washing; brushing teeth; or cleaning food preparation equipment, utensils, and tableware. Untreated tap water can be used for other household purposes (e.g., showering, laundry, or bathing). Adults, adolescents, and older children can wash, bathe, or shower; however, they should avoid swallowing any water. Toddlers and infants should be sponge-bathed.

Safe sources of water include the following:

- *commercially bottled water,*
- *water that has been disinfected for Cryptosporidium by:*
  - *boiling at a rolling boil for 1 minute (at altitudes greater than 6,562 feet [2,000 m], boil water for 3 minutes) or*
  - *distilling;*
- *water hauled from an approved public water supply in a covered sanitized container; or*
- *water from a licensed drinking water hauler truck.*

Upon rescission of a boil-water advisory

- *flush household pipes and faucets by running all coldwater faucets for 3 minutes each;*
- *discard ice and flush home automatic icemakers;*
- *make three batches of ice cubes and discard all three batches; and*
- *run water softener equipment through a regeneration cycle.*

Studies report that residents often continue to consume untreated water after issuance of a boil-water advisory, resulting in additional cases of the waterborne disease, because they did not hear about the advisory or understand the severity of the situation, the procedures, or the duration of the advisory.

Consequently, when boil-water advisories are issued, water supply operators, local governments, and public health officials should work to ensure that all residents are informed of the health risks and consequences of noncompliance by broad coverage through the local media. In small towns with limited media outlets, door-to-door delivery of the announcement might be considered.

Boil-water advisories should be issued with easy-to-understand instructions, including details about the correct procedures for boiling water or other acceptable modes of treatment, what activities necessitate using boiled water, and what to do when the boil-water advisory is rescinded. Residents should be informed that the boil-water advisory will be in effect until notification by the proper authorities.

Written information sheets are ideal. Boil-water advisories should be translated into Spanish, Vietnamese, or other languages commonly spoken by non-English-speaking residents in the affected community.

Special instructions might be needed by certain audiences (e.g., hospitals and clinics; renal dialysis units; nursing homes; child care facilities; dental offices; such commercial establishments as restaurants, hotels, convenience stores; and commercial ice producers). Authorities might need to release information pertinent to these audiences individually (i.e., not as a general news release). Such communications as blast faxes and notices through health alert networks are optimal methods for distributing information to these specialized audiences quickly. (See http://www.cdc.gov/crypto/gen_info/index.html for protocols that can be used with various specialized audiences.)

Question 7: What studies or investigations might you undertake to confirm the hypothesis that the public water supply was the source of Carrollton's cryptosporidiosis outbreak?

The following studies or investigations might help confirm the hypothesis that the public water supply was the source of the cryptosporidiosis:

- *a case-control study (**Note:** Lack of laboratory confirmation of many cryptosporidiosis cases at the time of this outbreak made a case-control study difficult);*
- *a community survey;*
- *an evaluation of the public water system (**Note:** Evaluation of the public water system includes such activities as an inspection of the source water, a tour of the water treatment facility, examination of water treatment processes and equipment, and record review at multiple locations. The evaluation is addressed in great detail in Section V.);*
- *collection and testing of historical water samples for total coliforms, fecal indicators, and Cryptosporidium (e.g., water from water bottles and ice in refrigerators, refrigerator filters, toilet tanks in houses where residents have been away, storage tanks, taps at seldom-used and dead-end locations, and ice from commercial ice plants); and*
- *testing of treated and untreated (raw) water from the public water system for Cryptosporidium oocysts.*

PART III. DESIGNING AN EPIDEMIOLOGIC STUDY TO TEST THE HYPOTHESIS

On January 25, a case-control study was undertaken among patients presenting at the local hospital emergency department. Case-patients were persons who had presented to the emergency department with abdominal pain or diarrhea (defined as three or more loose stools in a 24-hour period) since January 1. Control-subjects were patients presenting to the emergency room on the same dates as the case-patients but for non-gastrointestinal illnesses.

Twenty (80%) of 25 case-patients and 3 (33%) of 9 control subjects had been exposed to the public water supply at home or work (odds ratio: [OR] 8; P value = 0.03). The case-control study, however, was plagued with problems. Multiple patients initially selected as control subjects, but who were later excluded, reported having been ill with abdominal pain and diarrhea even though they had been examined at the emergency department for non-gastrointestinal illnesses.

Investigators questioned the validity of the results. Therefore, two simultaneous lines of investigation were undertaken to determine if the public water supply was the source of the outbreak: a community survey and an evaluation of the water treatment plant in Carrollton, Georgia.

Staff from the Carroll County Health Department met with epidemiologists from the Georgia Department of Human Resources to plan the community survey.

Question 8: What steps would you undertake to conduct a community survey?

Note: *What follows is a fairly detailed list of steps. Depending on the time available and the learning objectives for the students, the teaching approach might need to be adjusted. The critical points are that the survey should be carefully planned before it is executed, that the goals and the objectives of the survey drive decisions about how survey is conducted, and that a systematic approach should be taken so that the survey results provide valid and meaningful information.*

The following steps are typically used in conducting a community survey. For particular surveys, certain steps might overlap or occur in a slightly different order. Occasionally, steps will be omitted or additional steps added. These steps presume that hypotheses about the health problem of interest have already been developed.

1. *Define the purpose for the survey − The survey's purpose includes it's goals and objectives and how the results will be used. The survey should be developed with these goals and objectives in mind.*
2. *Determine the target population − The target population is based on the group to which the results of the survey will be generalized and who will be most likely to possess the information needed for the survey. The description of the target population typically includes demographic characteristics (e.g., age, sex, and occupation), location, and study period. The target population sometimes includes individual persons with certain characteristics and sometimes includes larger groups (e.g., entire households or patients of a particular health care provider) with certain characteristics.*
3. *Select the sample − Selecting the sample includes determining the method of sample selection (e.g., simple random sample, systematic sample, or cluster sample), the sample size, and how survey subjects will be selected. The goal is to represent the original target population as accurately as possible.*
4. *Identify information to be collected − Information that needs to be collected in a survey includes:*
   - *information pertinent to the topic of the survey that will be used to determine if the subject is an affected patient (e.g., signs and symptoms of disease and date of onset) or had a particular exposure (e.g., place of residence, source of water, place of work or school);*
   - *information necessary for the logistics of the survey (e.g., identifier for the participant, information to determine or confirm participant eligibility); and*

- *information necessary to examine confounders (i.e., factors that are associated with both the disease of interest and the exposure of interest that can affect the observed association between the disease and exposure of interest [e.g., sex, age, education, and socioeconomic status]).*

5. *Determine the best technique to collect survey information − Options for collecting survey information include face-to-face interviews, telephone interviews, or self-administered questionnaires. (The later includes Internet surveys, which were unavailable at the time of Carrollton's outbreak.) The means used to collect the necessary information is based on the time available to collect the information, likely costs and resources, characteristics of the target population, and the sensitivity of the information collected.*
6. *Create the questionnaire − Creating the questionnaire includes the exact wording of the questions and potential responses to the questions, the layout of each question, and the sequencing of the questions and skip patterns. Questionnaires (or questions) successfully used in other investigations can be modified for use in the current survey. For example, a generic questionnaire for a case-control study on cryptosporidiosis is available at http://www.cdc.gov/healthywater/emergency/toolkit/drinking-water-outbreak-toolkit.html.*
7. *Create supporting materials − An introduction to the survey is needed and typically includes the purpose of the survey, why the participant was selected, protection of the participant's confidentiality, the sponsor of the survey (i.e., who is funding the survey or who will be using the information), the survey's length, and contact persons). Additionally, consent forms, protocols for collecting clinical specimens, and health communication documents that can be accessed directly by survey participants or used by interviewers to answer participant questions will need to be developed.*
8. *Pilot-test survey materials − Pilot-testing allows identification of problems with the survey instrument before data collection begins. The goal is to determine not only if the questionnaire is user-friendly but also the validity of the information collected and the time necessary to complete the questionnaire. Pilot-testing often occurs in multiple phases. Investigators often start by asking selected accessible persons who were not involved in developing the materials to review them. Investigators might then test the questionnaire with members of the target population and administer the questionnaire as planned for the real survey.*
9. *Apply for human subjects review − Because a community survey involves interactions with human subjects, it will be subject to the human subjects guidelines established by the agency conducting the survey or overseeing its administration. Depending of the circumstances, the study protocol, questionnaire, and related materials might need to be reviewed and approved by an internal review board (often called an institutional review board or IRB) to ensure the wellbeing of survey participants and compliance with ethical standards.*
10. *Train interviewers − To ensure valid and uniform collection of survey information, interviewers should be trained in administration of the survey questionnaire. They should also learn how to answer questions from survey subjects and how to report problems to investigators.*
11. *Implement fieldwork − The primary focus of the fieldwork will be contacting participants and administering the questionnaire. Other field activities include keeping track of which participants have responded and which have not, following up with nonrespondents, monitoring survey execution, and troubleshooting problems as they arise). Designating one person to review all completed questionnaires immediately for problems is strongly advised.*
12. *Review and edit data − If the survey is not administered online, printed copies of questionnaires should be reviewed before they are entered into the computer database for completeness and legibility. Data-entry errors can be minimized by having the data entered into the database twice by two different persons and then comparing both entries. After being entered, a cross-tabulation of the data can be used to identify missing and nonsensical values that then can be corrected. Efforts should be made to identify study participants who do not meet eligibility criteria, excluding ineligible persons from data analyses, and determining definitions for various parameters to be included in the analyses.*

13. *Calculate response rates −The survey response rate is the proportion of the selected sample that actually participates in the survey and is a critical indicator of the representativeness of a sample. Response rates can be calculated in multiple ways. In the simplest approach, the response rate is the number of persons or households that complete the survey questionnaire divided by the number of persons or households that were in the sample and were eligible to participate in the survey.*
14. *Tabulate and analyze results − Analyses include characterization of the study population and a comparison of the study population with the original target population. Other analyses focus on the data elements critical to the goals and objectives of the survey, including the prevalence of illness and exposures of interest, and the association between illness and the exposures. Depending on the survey, performing and comparing these same analyses among subgroups of the study population also might be appropriate.*
15. *Interpret results − To be useful, survey results should be translated into meaningful information that can be used by others to take action. Interpretation includes not only the primary findings of the survey, but the uncertainty of the results (i.e., the margin of error), limitations of the survey that might influence the results or the ability to generalize the results to the intended target population, and how the survey findings fit with the findings from other studies.*
16. *Disseminate results − As a final step, the results of the survey should be shared with all persons involved in the survey's design, development, and conduct; their associated agencies; and persons responsible for undertaking the necessary public health actions.*

The goals of the community survey were to determine the number of persons affected by cryptosporidiosis in Carroll County and to examine the association between public water consumption, other possible risk factors, and gastrointestinal illness.

Question 9: How would you select a sample for the survey?

The goal in selecting a sample is to represent the original target population as accurately as possible. The sample should be similar to the target population with regard to all relevant characteristics, except that it includes fewer persons. Multiple approaches are available for selecting a sample including the following:

- *Simple random sampling − Simple random sampling gives every member of the population an equal chance of being selected for the sample. A listing of the population is obtained and members are randomly selected from the list.*
- *Systematic sampling − Systematic sampling is similar to simple random sampling in that it also gives every member of the population an equal chance of being selected. However, rather than randomly selecting participants from a listing of the population, a starting point on the list is randomly selected, and participants are selected on the basis of a sampling interval (e.g., every tenth person).*
- *Stratified random sampling − In stratified random sampling, the target population is divided into non-overlapping subsets (i.e., strata) on the basis of at least one characteristic (e.g., sex). A simple random or systematic sample is then selected within each stratum. Each member of a particular stratum has an equal chance of being selected; however, the probability of selection might differ between members in different strata.*
- *Cluster sampling −In cluster sampling, the population to be studied is divided into natural, geographically distinct groups or clusters (e.g., schools, villages, or camps). A sample of clusters is then selected by using simple random sampling, systematic sampling, or stratified random sampling. After the clusters are selected, all units within the selected clusters are included in the sample. No units from nonselected clusters are included in the sample.*

- *Multi-stage sampling − Multi-stage sampling is a complex form of cluster sampling. In the first stage, clusters (i.e., primary sampling units) are identified and a sample of the clusters is selected by using simple random sampling, systematic sampling, or stratified random sampling. In the second stage, units within the clusters (i.e., secondary sampling units) are randomly selected.*

If a population listing is available, simple random sampling and systematic sampling are conceptually easiest to implement. A stratified random sample should be used when the population can be divided into meaningful subsets and estimates for the different subsets are desired. Cluster sampling, including multistage sampling, is good to use when the population of interest is too large, cannot be enumerated, or is distributed widely. For results from a cluster sample to reach the same level of precision as a simple random sample, the sample size must be appreciably greater, which increases the needed resources. Cluster sampling also requires more complex statistical analysis to account for the mode of sampling.

For this outbreak and setting in which a listing of all potential survey subjects is available, simple random sampling (e.g., random-digit-dialing) or systematic sampling (e.g., selecting households from the telephone directory or a county census) are reasonable approaches. The investigator might want to stratify the population according to those who live within the city limits of Carrollton and those who live in Carroll County but outside of the city.

To select the survey sample investigators systematically selected 400 listings (i.e., households) from the Carroll County telephone directory that listed Carrollton telephone numbers separately from those outside Carrollton. A larger proportion of Carrollton telephone numbers were selected (i.e., were oversampled) to ensure that the sample included an adequate number of persons who had been exposed to the public water supply (i.e., the suspected source of the outbreak).

A GDHR epidemiologist drafted a questionnaire for the survey. The questionnaire was piloted with staff from the Carroll County Health Department who were not involved in the investigation.

Question 10: How would you collect information from selected households for the survey?

Options for collecting survey information include face-to-face interviews, telephone interviews, or self-administered questionnaires. The methods used to collect the necessary information will be based primarily on the time available to collect the information (i.e., the need for timely information to support necessary public health actions), likely costs and resources, characteristics of the target population, and the sensitivity of the information collected. The following discussion presents the advantages and disadvantages for each method of collecting the information.

Face-to-face interviews
Advantages: Results in higher response rates than telephone or self-administered questionnaires; can use more complex questionnaire designs (with skip patterns); results in more accurate recording of responses and more anecdotal information.
Disadvantages: Requires contacting subjects and arranging meetings; seems less anonymous to subjects than self-administered questionnaires; can result in less honest responses because subjects give answers they think the interviewer wants to hear; has increased potential for interviewer bias; is most costly in terms of time and resources (particularly if subjects are geographically dispersed).

Telephone interviews
Advantages: Is easier to access subjects than face-to-face interviews or self-administered questionnaires; usually results in higher response rates than self-administered questionnaires; can use more complex questionnaire designs (with skip patterns); results in more accurate recording of responses; is less costly than face-to-face interviews.
Disadvantages: Seems less anonymous to subjects than self-administered questionnaires; might result in less honest responses because subjects give answers they think the interviewer wants to hear; has potential for interviewer bias; is more costly than self-administered questionnaires; can result in a more biased sample because of increased screening of calls by homeowners (through answering machines and voicemail) and increased use of cellular phones.

Self-administered questionnaires
Advantages: Seems more anonymous to subjects; can result in more honest responses from subjects; takes less investigator time after questionnaires are received by subjects; is less expensive than face-to-face or telephone interviews.
Disadvantages: Greater care should be taken in developing the questionnaire so that it can be completed easily by the subject; requires additional time for sending questionnaires to subjects and waiting for return of responses; usually results in more errors in recording of responses; results in lower response rate and requires more follow-up to obtain completed surveys.

Information for the survey was to be collected through telephone interviews. By using the questionnaire developed by the GDHR epidemiologist, one adult in each selected household (referred to as the respondent) was to be asked his or her age and sex, place of employment (or school), food and restaurant exposure, home water source, amount of tap water consumed, consumption of ice, and exposures to children in child care centers and to farm animals. The respondent also was to be asked about the age, sex, and place of employment or school of all household members and whether the household member had been ill with abdominal pain or diarrhea (defined as three or more loose stools within a 24-hour period) since January 1.

On the afternoon of January 30, a total of 12 staff from GDHR and the Carroll County Health Department were trained to administer the survey questionnaire by the telephone. Starting that evening, they telephoned each household on the list.

Question 11: What activities or efforts might help to improve the survey response rate?

- *Inform survey participants of the survey before it occurs or during implementation of the survey, if sufficient time is unavailable before it starts. Survey participants can be notified individually or by a general notification of the community through the local media. Notifying survey participants beforehand allows participants to mentally prepare for the survey and become comfortable with the idea of participating.*
- *Provide potential participants sufficient background information to gain their interest. The subject will be more likely to participate if the topic is of interest or the goal seems worthy.*
- *Inform potential respondents of who is conducting the survey and what credentials they hold. Including a local connection (e.g., using the name of the local health department) often helps.*
- *Provide a telephone number that can be called to verify the authenticity of the survey. Establishing legitimacy can help convince potential respondents to participate in a survey.*
- *Inform potential participants about their rights, their privacy, and that no negative consequences of nonparticipation will result.*
- *Make survey questions clear and concise. If potential respondents have trouble understanding the questions or following the skip patterns, they will be less likely to participate or might not complete the survey.*

- *Keep the questionnaire short. Long questionnaires are less likely to be completed than short ones.*
- *Give careful thought to the ordering of the questions. Ideally, the early questions in a survey should be easy and pleasant to answer. Difficult and sensitive questions should be placed near the end after rapport has been established between the interviewers and the subject.*
- *Offer to answer questions at the end of the survey. The lure of additional information might drive certain participants to complete the entire questionnaire.*
- *Follow up with nonrespondents. Additional attempts should be made to reach nonrespondents. Attempts should occur at different times of the day, different days of the week, and on weekends.*
- *Follow through with analyzing the survey results and reporting them. It will not help with the current survey, but it will build credibility and goodwill for the next time a survey is undertaken.*

PART IV. ANALYSIS AND INTERPRETATION OF EPIDEMIOLOGIC RESULTS

By February 5, adult respondents were interviewed at 304 (76%) of the 400 telephone numbers. Fifty-six of the listings were disconnected numbers; 31 had no answer after three calls or had no adult available to complete the interview; and nine adult respondents refused to participate or did not complete the interview. Information was collected from the 304 adult respondents and 507 additional household members for a total of 811 household members.

Investigators calculated the overall attack rate among all household members and attack rates by residence and exposure to the public water supply. Investigators set a P value of 0.05 as the cutoff for statistical significance. The source of home water was based on information provided by the adult respondent from each household. County engineers determined the water supply for worksites and schools. Persons whose home, school, or worksite was supplied with public water were considered to have been exposed to the public water supply.

Of the 811 household members interviewed, 363 had been ill with abdominal pain or diarrhea (defined as three or more loose stools within a 24-hour period) since January 1. After adjusting for oversampling of households from Carrollton, the overall attack rate for the county was 40%. Attack rates varied by residence and exposure to the public water supply (Table 1).

Table 1. Occurrence of illness* by exposure among all household members, community survey, Carroll County, Georgia.

Exposure	Illness among exposed	Illness among not exposed	Relative risk	95% confidence interval	P value
Residence in Carrollton	293/543 (54%)	70/278 (25%)	2.2	1.7−2.5	<0.0001
Exposure to public water supply	299/489 (61%)	64/322 (20%)	3.1	2.4−3.9	<0.0001

*Abdominal pain or diarrhea (defined as three or more loose stools within a 24-hour period) since January 1.

Among the 489 household members exposed to the public water supply, the attack rate was 67% for females and 55% for males (relative risk: 1.2; 95% confidence interval 1.1−1.4; P value=0.01). Attack rates varied by age group, ranging from 52% to 72%. The highest attack rate was among persons aged 20−29 years, but these differences were not statistically significant.

Question 12: Interpret the survey findings.

Residents of the city of Carrollton were twice as likely as nonresidents to become ill. Persons who were exposed to the public water supply at home, school, or work were 3 times as likely to become ill as those who were not. Both findings were unlikely (i.e., less than 5 chances in 100) to have occurred because of chance alone.

The increased risk for infection among persons residing in Carrollton might reflect the fact that they were more likely to be exposed to the public water supply through their homes than people living in the county but outside of Carrollton city limits.

Among the 304 adult respondents to the survey, 182 were exposed to the public water supply and provided information on the average amount of water they consumed each day (Table 2).

Table 2. Occurrence of illness* among adult respondents exposed to the public water supply by average amount of water consumed a day, community survey, Carroll County, Georgia.

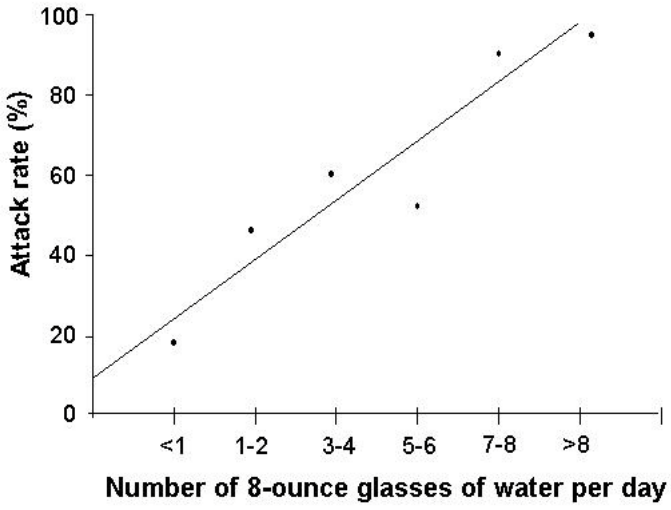
Average number of 8-ounce glasses of water consumed/day	Number ill	Number exposed	Attack rate
<1	2	11	18%
1−2	17	38	45%
3−4	28	48	58%
5−6	15	31	48%
7−8	21	25	84%
>8	26	29	90%
Total	109	182	60%

*Abdominal pain or diarrhea (defined as three or more loose stools within a 24-hour period) since January 1.

Question 13: Graph and interpret the association between water consumption and the occurrence of illness

Interpretation: As the average number of glasses of water consumed each day increased, the attack rate also increased. This dose-response finding supports the conclusion that the water was the source of the outbreak.

Figure A. Occurrence of illness among adult respondents exposed to the public water supply by average amount of water consumed a day, community survey, Carroll County, Georgia. (INSTRUCTOR VERSION ONLY)



Among adult respondents exposed to the public water supply, the higher attack rate among females remained significant even after controlling for age and water consumption. No significant association was identified between illness and any other exposure studied (e.g., exposure to specific foods, child care centers, farm animals, or other ill persons).

Question 14: On the basis of Table 1, 20% of persons not exposed to the public water supply became ill. If the public water supply was the source of the outbreak, what explanations exist for these persons becoming ill?

If the public water supply was the source of the outbreak, multiple possible explanations exist for illness among persons with no reported exposure to the water at home, school, or work

- *The illness was caused by something other than cryptosporidiosis. Abdominal pain and diarrhea are not specific for cryptosporidiosis alone.*
- *Ill persons were exposed to public water at places other than at home, school, or work (e.g., homes of friends or family, grocery stores, or restaurants) and forgot to mention these exposures in responding to the questionnaire or during the interview.*
- *The persons were exposed through secondary spread of illness from someone who had been exposed to the public water supply. Examination of the epidemic curve for the outbreak might indicate the role of secondary spread. A slow return in the number of cases to baseline is evidence of secondary spread of infection.*
- *Other sources of cryptosporidiosis existed in the community (e.g., cattle).*
- *The source of the outbreak was not the public water supply.*

PART V. ENVIRONMENTAL STUDIES AND WATER INVESTIGATION

On January 25, an evaluation of the Carrollton water system was initiated by federal and local engineers.

Question 15: What activities would you include in the evaluation of a public water treatment plant? With whom would you talk? What records or data sources would you review?

Note: *The quality of treated water is affected by multiple variables that interact in a complex manner. Therefore, the investigation team should include persons who have extensive knowledge of water treatment methods and plant engineering (e.g., environmental health specialists, utility engineers).*

Activities
Because every water treatment plant differs, the activities included in the evaluation of any particular plant will also vary (and can vary depending on current plant conditions). Investigators often undertake the following activities in the evaluation of water treatment plants:

Determine the quality of raw water
- *Collect information on the source of the water for the plant and means in place to protect the source from contamination.*
- *View maps of the watershed and tour the area.*
- *Collect information on conditions likely to affect the quality of the water from that source (e.g., construction, flooding, spring run-off, presence of farm animals or wildlife, waste water outflows at the water treatment plant).*
- *Inspect the wellhead (ground water) or intake point (surface water).*

Describe the water treatment process
- *Review blueprints and diagrams of the plant.*
- *Tour the plant.*
- *Collect detailed information on procedures used to treat water, including chemicals added and dosages, techniques for adding and mixing chemicals, order of addition of chemicals, settling time, contact time, and type of filtration.*
- *Observe procedures used to treat water.*
- *Collect information about recent changes in water treatment procedures.*
- *Inspect equipment used in water treatment (e.g., chlorine feeding equipment, sedimentation tanks, and filters) and collect information on maintenance or breakdown of equipment.*
- *Collect information on plant hydraulics and determine water flow rates and flow patterns.*
- *Inspect equipment used to monitor flow rates or chemical treatment processes.*

Determine the effectiveness of the water treatment process
- *Collect untreated (raw) and treated water specimens for testing for total coliforms, fecal indicators (e.g., E. coli), turbidity, and possibly the causative agent.*
- *Ascertain routine testing procedures used to determine quality of water, including frequency, timing, and how recorded and quality-control testing.*
- *Review routine test results for period of interest (e.g., residual disinfectant, pH, and turbidity).*
- *Measure temperature and pH of raw water.*
- *Measure disinfectant residual of treated water.*
- *Calculate contact time (i.e., period between introduction of disinfectant and when water is used).*
- *Collect historical samples of treated water (e.g., water bottles, ice, and filters in refrigerators; toilet tanks in houses where residents have been away; storage tanks; taps at seldom-used and dead-end locations; and ice from commercial ice plants).*

Determine the integrity of the water distribution system

- *Inspect holding tanks.*
- *Collect samples from holding tanks and test for chlorine residual and total coliforms or indicators of fecal contamination.*
- *Examine water distribution maps.*
- *Collect samples from taps and test for chlorine residual and total coliforms or indicators of fecal contamination.*
- *Collect information on unusual events that might negatively affect the water system (e.g., damage to pipes in distribution system, pump failures, draining distribution reservoirs, or massive pumping to fight fires that can produce low pressures and resultant contamination through cross-connections or back-siphonage [i.e., reversal of normal flow in a water distribution system caused by negative pressure in the supply pipe]).*

Persons who should be consulted

- *Water treatment plant superintendent and operators*
- *Maintenance technicians*
- *Laboratorians who oversee water-quality tests*
- *Engineers who designed water treatment plant*
- *Engineers or state agency employees who approved water treatment plant design*
- *Consulting engineers knowledgeable of water treatment facilities, water system hydraulics, or other specialty area*
- *Governmental regulators who oversee the water utility's compliance with drinking water regulations*

Records and data sources of interest

- *Results of routine water-quality tests (e.g., total coliform counts, fecal indicators, if any, turbidity, and total and residual chlorine) of both untreated and treated water and monitoring triggers*
- *Records of water treatment procedures (e.g., logs of chemicals used and dosages)*
- *Logs of system maintenance and repairs at the plant or to the water distribution system*
- *Water customers' complaint log*
- *Records of damage or repairs in and around water distribution system (e.g., water main breaks, sewer system maintenance, and road repairs)*
- *Weather reports that might reflect conditions for increased contamination of surface water supplies (e.g., flooding, low temperatures, and spring runoff)*

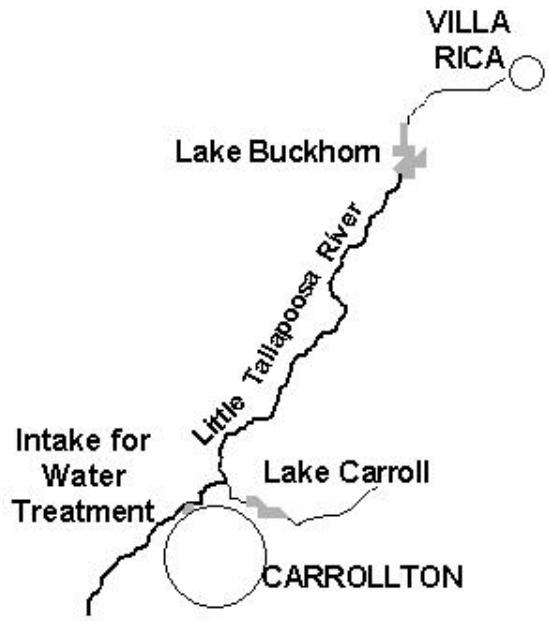
The engineers met first with the water system superintendent. The superintendent began by describing the source of water for the public water supply.

The Carrollton water system drew surface water from the Little Tallapoosa River and two reservoirs (Figure 2). The river begins near the town of Villa Rica and flows in a southwesterly direction to Carrollton, predominantly through hayfields and pastureland. Lake Buckhorn was used to supplement city water supplies when necessary. The city had no restrictions on the recreational uses of this reservoir and did not control a buffer strip around the reservoir.

The city raw water intake and pump were located on the northwest side of Carrollton. Lake Carroll, on the northeast side of Carrollton, acted as water storage impoundment for the water system. Water was drawn from Lake Carroll during periods of drought and high demand.

The water system superintendent showed the engineers a blueprint of the plant and led them on a tour of the treatment facility. The engineers interviewed the six plant operators and a maintenance technician to learn about water treatment operations at the facility.

Figure 2. Diagram of the Little Tallapoosa River between Villa Rica and Carrollton, Georgia



Question 16: What are the typical steps in the treatment of surface water at a public water treatment plant?

The amount and type of treatment applied by a public water system varies with the source type and quality of the raw water. The most commonly used steps in the treatment of surface water include flocculation and sedimentation, filtration, and disinfection

- *Flocculation refers to water treatment processes that coagulate very small particles (<0.1 µm) suspended in the water into larger particles (called floc), which settle out of the water as sediment. Alum and iron salts or synthetic organic polymers typically are generally used to promote coagulation. Sedimentation occurs naturally as flocculated particles settle out of the water. Coagulation and flocculation are effective at removing fine suspended particles that attract and hold bacteria, viruses, and parasites to their surface. They also remove certain organic matter present in water.*

- *Filtration removes finer particles from the water (e.g., clays and silts, natural organic matter, precipitates from other treatment processes, iron and manganese, and microorganisms) and enhances the effectiveness of disinfection. (Note: Filters do not remove such contaminants as gas, oil, pharmaceuticals, and biotoxins.) Filtration is based on simultaneous actions, including mechanical straining between the particles of the filter (i.e., the pores), adsorption of particles to filter materials as the result of physical forces (e.g., van der Waals and Coulombs forces), and biochemical processes in the biologic layer of a filter (i.e., a thin film of active microorganisms*

sometimes called the Schmutzdecke). Filters can be made of different materials, but sand is the most common for industrial filtration. Sand filters typically have pore sizes of approximately 60−100 µm.

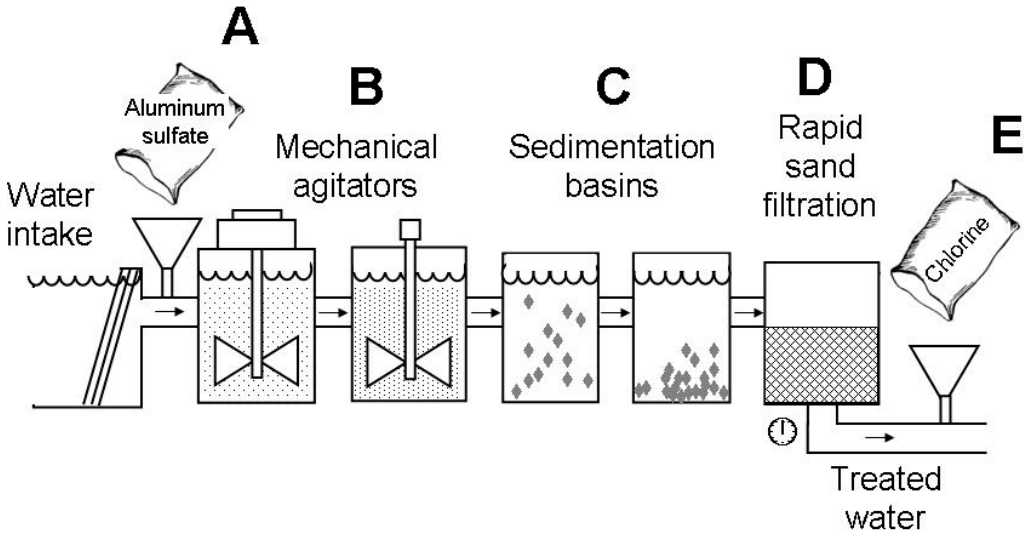
- *Disinfection is used to ensure that potentially dangerous microbes (not removed by sedimentation or filtration) are killed. Chlorine is a commonly used, effective disinfectant. It has a residual effect in the pipes that distribute water to homes and businesses that can be measured throughout the distribution system. Ozone and ultraviolet (UV) radiation also are effective disinfectants but neither are effective in controlling biologic contaminants in the distribution pipes (i.e., they leave no residual in the system).*

  *(**Note:** Not all microorganisms are equally susceptible to different forms of disinfection. For example, protozoal parasites [e.g., Giardia and Cryptosporidium] require higher concentrations of chlorine, or longer contact times, for inactivation than the majority of bacteria, but are more susceptible to UV radiation than bacteria.)*

Water at the Carrollton water system was initially treated by adding a coagulant, aluminum sulfate (Figure 3A). Coagulant causes smaller particles in the water to aggregate into larger particles (called floc) that are more likely to settle out. Addition of the aluminum sulfate was followed by rapid mixing by using mechanical agitators to promote the aggregation of particulates (Figure 3B). The aggregated particles were allowed to settle out in a sedimentation basin (Figure 3C). The water was then filtered by using rapid sand filtration (Figure 3D).

Chlorine in the form of powdered calcium hypochlorite was added to the filtered water in predetermined amounts by using an automatic feed pump (Figure 3E). The chlorine was fed directly into a retention tank along with the water so that chlorine concentration and contact time could be controlled before it was released into the distribution system. Lime was also added to the water to minimize leaching of lead and copper in home plumbing systems.

Figure 3. Diagram of Carrollton water treatment process



From Hayes EB, Division of Parasitic Diseases, CDC, Personal Communication, 1989.

On the basis of information provided by the plant operators, 10−20 rapid sand filters were in operation at the water treatment plant at any one time, depending on water demand. The filters were cleaned on a routine basis by using backwashing, a process that involves reversing the flow of water back through the filter to remove the solids trapped in the filter media and allowing the filters to sit for a period before being placed online (i.e., were allowed to ripen). All backwash water was diverted to sewage.

Filters that had been taken offline were also backwashed before being restarted. Starting filters without backwashing can discharge dirt, aggregated particles, and microorganisms from the filter beds into the treated water.

The engineering evaluation revealed multiple deviations from normal operations at the Carrollton water system during the prior 2 months. Mechanical agitators had been removed in December in anticipation of a scheduled replacement but still had not been replaced. Filters were sometimes restarted without first being backwashed. During the first week of January, the number of filters restarted increased from a weekly average of 22 to 38 because water use increased when students returned to the college after the holidays.

The engineers reviewed plant water-quality data (e.g., records of pH, temperature, turbidity, and total coliform counts) of untreated and treated water. They measured the turbidity of the water at the intake and the outflow from the facility and collected samples of raw and treated water to test for coliforms and *Cryptosporidium*.

Question 17: What does turbidity indicate? Why would the investigators be interested in turbidity of both untreated and treated water?

Turbidity is the clarity of a liquid and is an expression of the optical property that causes light to be scattered and absorbed by particles and molecules rather than transmitted in straight lines through a liquid. Turbidity is commonly assessed by using an instrument called a nephelometer (nephele is Greek for cloudy) and is measured in nephelometric turbidity units (NTUs). As a liquid becomes more turbid, NTUs increase and vice versa.

Turbidity in water is caused by impurities (e.g., clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms). Typical sources of turbidity in drinking water include the following:

- *waste discharges;*
- *runoff from watersheds, especially those that are disturbed or eroding (e.g., after heavy rainfall);*
- *algae or aquatic weeds and products of their breakdown in water reservoirs, rivers, or lakes;*
- *humic acids and other organic compounds from plant or leaf decay in water sources;*
- *high iron concentrations that give water a rust-red coloration, mainly in ground water; and*
- *air bubbles and particles from the treatment process (e.g., hydroxides or lime softening).*

Although turbidity was once considered as a mostly aesthetic characteristic of drinking water, substantial evidence exists that controlling turbidity is a safeguard against pathogens. Turbidity in raw water increases the chlorine demand and the amount of chlorine that must be added to achieve the desired residual chlorine level. Turbidity can provide food for pathogens and protect them from disinfectants. The particles adsorb pathogens and, if not removed, can promote regrowth of pathogens in the distribution system.

Although turbidity is not a direct indicator of health risk, studies report a strong association between the removal of turbidity and the removal of protozoa. Research indicates that Cryptosporidium is most reliably removed when water turbidity is consistently maintained at 0.1 NTU or lower.

On the basis of water-quality records, treated water from the Carrollton water system was at all times in compliance with U.S. Environmental Protection Agency and state of Georgia limits for turbidity, coliform bacteria, and free chlorine residual. At the time of the outbreak, federal guidelines required that turbidity not exceed 5 nephelometric turbidity units (NTUs) on any one reading or exceed 1 NTU in more than 5% of the daily samples in any month. For this size water system, total coliforms were tested on a monthly basis.

Treated water samples obtained from the water system during the engineering evaluation had turbidity ranging from 0.1 to 0.5 NTUs. These samples, however, demonstrated that particles as large as 100 µm were passing into the town's water supply. All samples collected during the evaluation were negative for total coliforms.

Cryptosporidium oocysts were identified in samples of treated water taken from the treatment plant and from four dead-end water mains (i.e., mains that supply water from only one direction such that water stops circulating and becomes stagnant), including one at the college first reporting the outbreak.

Question 18: How is it possible that treated water from the public water system was negative for coliforms yet contained *Cryptosporidium* oocysts?

The CT factor (chlorine contact time, calculated by multiplying the concentration of chlorine by the time a particular pathogen must be exposed to that concentration of chlorine to inactivate a certain percentage of the pathogen) can be used to compare the effectiveness of chlorine against different pathogens. Higher CT factors indicate higher resistance to chlorine and vice versa.

Compared with coliform bacteria, Cryptosporidium oocysts are highly resistant to chlorine (Table A). Therefore, chlorination of the Carrollton water system probably was adequate to kill coliform bacteria but inadequate to inactivate Cryptosporidium oocysts.

Table A. The concentration of chlorine needed to inactivate over 99% of a particular pathogen in a specimen times the time the pathogen was exposed to that concentration (CT factor) for selected disease-causing bacteria, viruses, and protozoa. (INSTRUCTOR VERSION ONLY)*

Microbe	*CT factor*
E. coli	*<0.25*
Hepatitis A	*<0.41*
Shigella sonnei	*0.5*
Campylobacter jejuni	*0.5*
Polio virus	*6.36*
Giardia	*45*
Cryptosporidium	*15,200*

**From Amelia Kasper, Division of Parasitic Diseases, CDC, Personal Communication, December 20, 2007.*

In addition, filtration techniques used in the Carrollton water treatment process allowed particles as large as 100 µm to pass into treated water. Because Cryptosporidium oocysts are approximately 3−4 µm in size, viable oocysts were able to pass into the treated water in sufficient numbers to cause widespread illness.

Samples obtained on February 4−5 from Lake Carroll and streams that drained into the Little Tallapoosa River above the treatment plant were positive for *Cryptosporidium* but samples taken from the river itself, upstream from the treatment plant, were negative. Samples of treated water taken as controls from a nearby town with a separate water source were also negative.

Fresh stool samples were collected from 67 of 226 cattle (including three calves) pastured in the watershed of the Little Tallapoosa River. No outbreaks of diarrheal illness were reported in regard to these cattle. *Cryptosporidium* was present in stool samples obtained from 3 of the 67 cattle tested. Because of the low level of infection among cattle in Carroll County and the discordant distribution of positive cattle fecal samples and positive water sample sites, investigators could not conclude that the outbreak was caused by cryptosporidiosis among the cattle.

On the basis of data provided by the National Weather Service, environmental conditions at the time of the outbreak might have increased the level of surface water contamination. Approximately 10 inches (25 cm) of rain and snow had fallen during January 15−22, raising the possibility of surface runoff.

Furthermore, a sewage pipe overflow was discovered in mid-February in a wooded area above the water treatment plant. The duration of the overflow, caused by a blocked major sewer line, could not be determined. When dye was released at the overflow point, it reached the Little Tallapoosa River and the water treatment plant in approximately 6 hours. The sewage spill might have augmented the load of *Cryptosporidium* reaching the water treatment plant.

PART VI. CONTROL AND PREVENTION MEASURES

On February 6, the Carrollton water system superintendent and plant operators met with federal and local engineers to determine what steps were necessary to ensure the safety of the public water supply and to lift the boil-water advisory.

Question 19: What water treatment measures are effective against *Cryptosporidium*?

Given the resistance of Cryptosporidium oocysts to chlorination, adequate filtration of water is the most effective treatment measure. Filtration techniques should remove particles greater than 1 µm in diameter to be effective. Special attention should be given to the condition of the filters, rate of flow of water through the filters, and filter maintenance (e.g., means used to clean and restart filters that have been offline and allowing the filter to ripen before being used [i.e., allowing the sand particles to develop a thin film of active microorganisms that increase the filter's effectiveness at removing particles less than 100 µm in diameter]).

Improvements in the flocculation and sedimentation will improve the effectiveness of filtration by increasing the floc size and removing large particles before filtration. Replacement of the mechanical agitators will help in this regard.

The water treatment facility installed the missing mechanical agitators and upgraded their turbidity-monitoring equipment. The new equipment measured turbidity continuously throughout each day on each filter, recording readings at 15-minute intervals. An alarm sounded and the system automatically shut down if the turbidity of filtered water exceeded 0.3 NTU. Total coliform counts were monitored daily.

Plant employees were reminded of the need to backwash filters before restarting them and the plant operators were to ensure that procedures were followed. The blocked sewer line was repaired and the sewage spill was cleaned up. In addition, the entire water system was flushed in an attempt to remove residual oocysts.

Question 20: How would you monitor the effectiveness of these control measures?

The following can help with monitoring the effectiveness of the control measures:

- *Water monitoring*
- *Intermittent inspections of water treatment equipment (to see if properly installed and working)*
- *Monitoring the turbidity of treated water*
- *Testing treated water for Cryptosporidium oocysts*

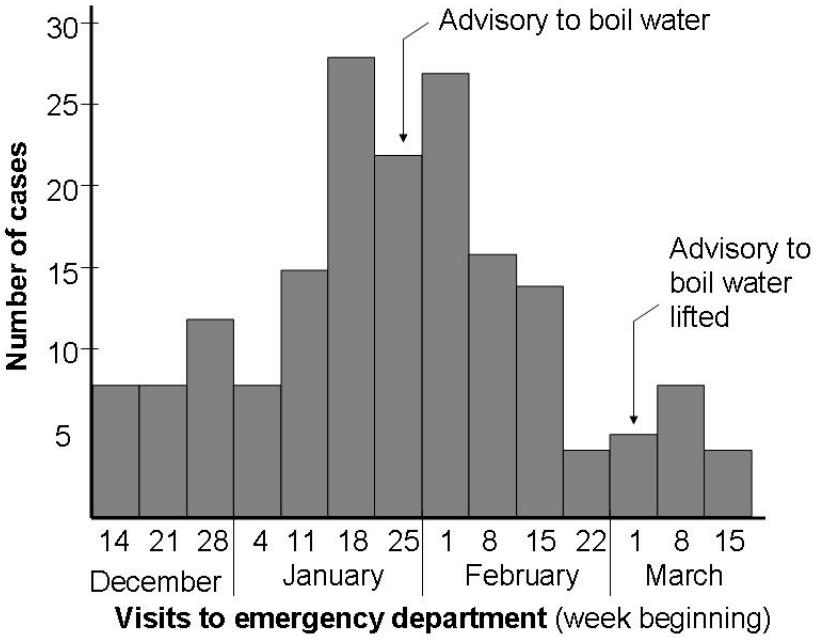
Surveillance for disease

- *Human cases of cryptosporidiosis*
- *Visits for diarrhea or abdominal pain to the local hospital emergency department*
- *Visits for diarrhea or abdominal pain to the college infirmary*

Physicians should be taught about the signs and symptoms usually associated with cryptosporidiosis and the need to request special testing to detect Cryptosporidium oocysts in stool specimens. Laboratories should be alerted to report increased requests for stool cultures or examinations and to report laboratory-confirmed cases of cryptosporidiosis.

Local clinicians were encouraged to test patients for *Cryptosporidium* if a patient experienced acute gastroenteritis and had symptoms for longer than 3 days. The number of visits for gastroenteritis at the local hospital emergency department returned to baseline (Figure 4).

Figure 4. Numbers of emergency department visits by patients with acute gastroenteritis, Carroll County, Georgia, by week of visit, December−March.



Changes at the water treatment facility improved the turbidity of treated water, consistently removing particles larger than approximately 1 micrometer. *Cryptosporidium* oocysts are approximately 3−4 µm in size. A sample of water taken on February 11 revealed no oocysts. The consistently low turbidity readings resulted in the lifting of the boil-water advisory on March 2.

For a complete report of the investigation of the cryptosporidiosis outbreak in Carrollton, Georgia, see NORS Report_Cryptosporidiosis Outbreak in Georgia.pdf (i.e., the CDC 52.12 report that was completed for the outbreak).

EPILOGUE

Public water systems are regulated under the Safe Drinking Water Act (SDWA) of 1974 and its subsequent 1986 and 1996 amendments.[2] The act authorizes the EPA to set national standards to protect public drinking water and its sources against naturally occurring or manmade contaminants. Information reported on waterborne outbreaks through CDC's Waterborne Disease and Outbreaks Surveillance System is used, in part, to assess whether EPA regulations for water treatment and water-quality monitoring are adequate to protect the public's health.[3-7]

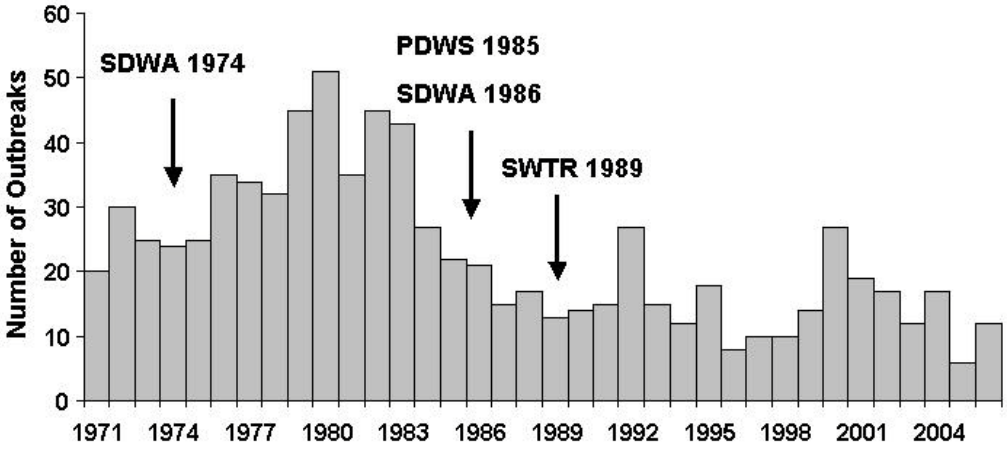
Before the Carrollton outbreak, *Cryptosporidium* had been linked only with waterborne outbreaks in communities using unfiltered surface water for drinking. The outbreak in Carrollton was the first reported contamination of a filtered surface water system. Although the sand filtration and chlorination used at the water treatment facility met all water-quality standards at the time, suboptimal mechanical agitation and filtration probably allowed the parasite to pass into the drinking water supply.

A similar outbreak occurred in 1993 in the greater Milwaukee area in which more than 400,000 persons were affected. In the Milwaukee outbreak, *Cryptosporidium* oocysts in untreated surface water from Lake Michigan entered the water treatment plant where existing coagulation and filtration methods allowed them to enter the public water supply. [8] As with the Carrollton outbreak, water quality measures for the treated water were within EPA required limits.

These outbreaks, along with others, demonstrated that *Cryptosporidium* can contaminate filtered public water systems, even when the water quality is within regulatory limits for coliform bacteria, chlorine, and turbidity. This realization prompted EPA to reconsider water treatment regulations and the issuance of Interim Enhanced Surface Water Treatment Rule (IESWTR) 63 FR 69478–69521(December 16, 1998, Vol. 63, No. 241). This rule increased turbidity performance standards for public water treatment systems and increased the frequency of monitoring requirements.[9]

The increasingly stringent EPA regulations for treatment of surface water have had a positive effect on the safety of treated drinking water in the United States. Since the early 1990s, the number of reported waterborne outbreaks associated with either untreated or inadequately treated surface water has decreased substantially (Figure 5).

Figure 5. Number of waterborne-disease outbreaks associated with drinking water (n = 814), by year — United States, 1971–2006.



Source: CDC Waterborne Disease and Outbreak Surveillance System
SDWA = Safe Drinking Water Act; PDWS = National Primary Drinking Water Standards; SWTR=Surface Water Treatment Rule.

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APPENDIX A: CDC Cryptosporidiosis Fact Sheet

Available at http://www.cdc.gov/crypto/gen_info/infect.html

What is cryptosporidiosis?
Cryptosporidiosis is a diarrheal disease caused by microscopic parasites, Cryptosporidium, that can live in the intestine of humans and animals and is passed in the stool of an infected person or animal. Both the disease and the parasite are commonly known as "Crypto." The parasite is protected by an outer shell that allows it to survive outside the body for long periods of time and makes it very resistant to chlorine-based disinfectants. During the past 2 decades, Crypto has become recognized as one of the most common causes of waterborne disease (recreational water and drinking water) in humans in the United States. The parasite is found in every region of the United States and throughout the world.

How is cryptosporidiosis spread?
Cryptosporidium lives in the intestine of infected humans or animals. An infected person or animal sheds Crypto parasites in the stool. Millions of Crypto germs can be released in a bowel movement from an infected human or animal. Shedding of Crypto in the stool begins when the symptoms begin and can last for weeks after the symptoms (e.g., diarrhea) stop. You can become infected after accidentally swallowing the parasite. *Cryptosporidium* may be found in soil, food, water, or surfaces that have been contaminated with the feces from infected humans or animals. Crypto is not spread by contact with blood.

Crypto can be spread:

- By putting something in your mouth or accidentally swallowing something that has come into contact with stool of a person or animal infected with Crypto.
- By swallowing recreational water contaminated with Crypto. Recreational water is water in swimming pools, hot tubs, Jacuzzis, fountains, lakes, rivers, springs, ponds, or streams. Recreational water can be contaminated with sewage or feces from humans or animals.
- By swallowing water or beverages contaminated with stool from infected humans or animals.
- By eating uncooked food contaminated with Crypto. Thoroughly wash with uncontaminated water all vegetables and fruits you plan to eat raw. See below for information on making water safe.
- By touching your mouth with contaminated hands. Hands can become contaminated through a variety of activities, such as touching surfaces (e.g., toys, bathroom fixtures, changing tables, diaper pails) that have been contaminated by stool from an infected person, changing diapers, caring for an infected person, and handling an infected cow or calf.
- By exposure to human feces through sexual contact.

What are the symptoms of cryptosporidiosis?
The most common symptom of cryptosporidiosis is watery diarrhea. Other symptoms include:

- Stomach cramps or pain
- Dehydration
- Nausea
- Vomiting
- Fever
- Weight loss

Some people with Crypto will have no symptoms at all. While the small intestine is the site most commonly affected, Crypto infections could possibly affect other areas of the digestive tract or the respiratory tract.

How long after infection do symptoms appear?
Symptoms of cryptosporidiosis generally begin 2 to 10 days (average 7 days) after becoming infected with the parasite.

How long will symptoms last?
In persons with healthy immune systems, symptoms usually last about 1 to 2 weeks. The symptoms may go in cycles in which you may seem to get better for a few days, then feel worse again before the illness ends.

Who is most at risk for cryptosporidiosis?
- People who are most likely to become infected with Cryptosporidium include:
- Children who attend day care centers, including diaper-aged children
- Child care workers
- Parents of infected children
- People who take care of other people with cryptosporidiosis
- International travelers
- Backpackers, hikers, and campers who drink unfiltered, untreated water
- People who drink from untreated shallow, unprotected wells
- People, including swimmers, who swallow water from contaminated sources
- People who handle infected cattle
- People exposed to human feces through sexual contact

Contaminated water may include water that has not been boiled or filtered, as well as contaminated recreational water sources (e.g., swimming pools, lakes, rivers, ponds, and streams). Several community-wide outbreaks of cryptosporidiosis have been linked to drinking municipal water or recreational water contaminated with Cryptosporidium.

Who is most at risk for getting seriously ill with cryptosporidiosis?
Although Crypto can infect all people, some groups are likely to develop more serious illness.
- Young children and pregnant women may be more susceptible to the dehydration resulting from diarrhea and should drink plenty of fluids while ill.
- If you have a severely weakened immune system, you are at risk for more serious disease. Your symptoms may be more severe and could lead to serious or life-threatening illness. Examples of persons with weakened immune systems include those with AIDS; cancer and transplant patients who are taking certain immunosuppressive drugs; and those with inherited diseases that affect the immune system.

What should I do if I think I may have cryptosporidiosis?
If you suspect that you have cryptosporidiosis, see your health care provider.

How is a cryptosporidiosis diagnosed?
Your health care provider will ask you to submit stool samples to see if you are infected. Because testing for Crypto can be difficult, you may be asked to submit several stool specimens over several days. Tests for Crypto are not routinely done in most laboratories. Therefore, your health care provider should specifically request testing for the parasite.

What is the treatment for cryptosporidiosis?
Nitazoxanide has been FDA-approved for treatment of diarrhea caused by *Cryptosporidium* in people with healthy immune systems and is available by prescription. Consult with your health care provider for more information. Most people who have healthy immune systems will recover without treatment.

Diarrhea can be managed by drinking plenty of fluids to prevent dehydration. Young children and pregnant women may be more susceptible to dehydration. Rapid loss of fluids from diarrhea may be especially life threatening to babies. Therefore, parents should talk to their health care provider about fluid replacement therapy options for infants. Anti-diarrheal medicine may help slow down diarrhea, but a health care provider should be consulted before such medicine is taken.

People who are in poor health or who have weakened immune systems are at higher risk for more severe and more prolonged illness. The effectiveness of nitazoxanide in immunosuppressed individuals is unclear. HIV-positive individuals who suspect they have Crypto should contact their health care provider. For persons with AIDS, anti-retroviral therapy that improves immune status will also decrease or eliminate symptoms of Crypto. However, even if symptoms disappear, cryptosporidiosis is often not curable and the symptoms may return if the immune status worsens.

I have been diagnosed with cryptosporidiosis, should I worry about spreading the infection to others?
Yes, *Cryptosporidium* can be very contagious. Infected individuals should follow these guidelines to avoid spreading the disease to others:

1. Wash your hands frequently with soap and water, especially after using the toilet, after changing diapers, and before eating or preparing food.

2. Do not swim in recreational water (pools, hot tubs, lakes, rivers, oceans, etc.) if you have cryptosporidiosis and for at least 2 weeks after the diarrhea stops. You can pass Crypto in your stool and contaminate water for several weeks after your symptoms have ended. You do not even need to have a fecal accident in the water. Immersion in the water may be enough for contamination to occur. Water contaminated in this manner has resulted in outbreaks of cryptosporidiosis among recreational water users.

Note: You may not be protected in a chlorinated recreational water venue (e.g., swimming pool, water park, splash pad, spray park) because *Cryptosporidium* is chlorine-resistant and can live for days in chlorine-treated water.

3. Avoid sexual practices that might result in oral exposure to stool (e.g., oral-anal contact).

4. Avoid close contact with anyone who has a weakened immune system.

5. Children with diarrhea should be excluded from child care settings until the diarrhea has stopped.

This fact sheet is for information only and is not meant to be used for self-diagnosis or as a substitute for consultation with a health care provider. If you have any questions about the disease described above or think that you may have a parasitic infection, consult a health care provider.

Page last reviewed: January 22, 2009
Page last updated: January 22, 2009
Content source: Division of Parasitic Diseases, National Center for Zoonotic, Vector-Borne, and Enteric Diseases

APPENDIX B: Boil Water Advisory for Public Users of Public Water Supply

Available at: http://www.cdc.gov/crypto/health_professionals/bwa/public.html

During a boil water advisory

General Procedures
Do not serve or consume:
- water that has not been disinfected,
- ice or drinks made with water that has not been disinfected, or
- raw foods rinsed with water that has not been disinfected.

Discontinue service of equipment with water line connections (e.g., water coolers, automatic ice makers, etc.).

Discard ice made prior to the boil water advisory issuance and discontinue making ice. Use commercially-manufactured ice.

Drinking Water
For drinking water, use:
- commercially-bottled water
- *and/or water that has been disinfected for* Cryptosporidium *by:*
  - boiling at a rolling boil for 1 minute (at altitudes greater than 6,562 feet [>2,000 m], boil water for 3 minutes), or
  - distilling
- and/or water hauled from an approved public water supply in a covered sanitized container
- and/or water from a licensed drinking water hauler truck.

Note: Although chemicals (e.g., bleach) are sometimes used for disinfecting small volumes of drinking water for household use, chemical disinfection is generally not recommended for commercial establishments because of the lack of onsite equipment for testing chemical residuals. Furthermore, *Cryptosporidium* is poorly inactivated by chlorine or iodine disinfection. *Cryptosporidium* can be removed from water by filtering through a reverse osmosis filter, an "absolute one micron" filter, or a filter certified to remove *Cryptosporidium* under NSF International Standard #53 or #58 for either "cyst removal" or "cyst reduction." (see A Guide to Water Filters for more information) However, unlike boiling or distilling, filtering as just described will not eliminate other potential disease-causing microorganisms, such as bacteria and viruses. Ultraviolet light treatment of water is not effective against *Cryptosporidium* at normally-used levels.

Cooking and Food Preparation
For cooking and food preparation:
- Discard any ready-to-eat food prepared with water prior to the discovery of the water contamination.
- Prepare/cook ready-to-eat food using the drinking water alternatives listed above and/or restrict the menu to items that do not require water.

For cooking and food preparation equipment/utensils/tableware:
- Use single service/use articles.
  and/or
  Clean and sanitize equipment/utensils/tableware using the drinking water alternatives listed above. Follow the established procedures to wash, rinse, and sanitize.

- *Cryptosporidium* on equipment/utensils/tableware may be disinfected using dishwashing machines that have a dry cycle or a final rinse that exceeds 113°F for 20 minutes or 122°F for 5 minutes or 162°F for 1 minute.
- Discontinue operations when inventories of clean equipment/utensils/tableware are exhausted.

Handwashing
For handwashing, wet hands with the drinking water alternatives listed above and apply liquid, bar, or powder soap.

- Rub hands together vigorously for 20 seconds, making sure to lather and scrub all surfaces, including backs of hands, wrists, between fingers, and under fingernails.
- Rinse hands well with running water – if running water is not available, water may be poured on the hands by another person.
- Dry hands with paper towels or an air dryer.
- Use the paper towels to turn off the faucet, if applicable.

Note: *Cryptosporidium* is not killed by alcohol gels and hand sanitizers. Soap and disinfected water are specifically recommended for preventing cryptosporidiosis.

When the boil water advisory is cancelled
- Flush pipes and faucets. Run cold water faucets continuously for at least 5 minutes.
- Flush water coolers. Run coolers with direct water connections for 5 minutes.
- Flush home automatic ice makers. Make three batches of ice cubes and discard all three batches.
- Run water softeners through a regeneration cycle.
- Drain and refill hot water heaters set below 113°F.
- Change all point-of-entry and point-of-use water filters, including those associated with equipment that uses water.

Page last reviewed: January 22, 2009
Page last updated: January 22, 2009
Content source: Division of Parasitic Diseases, National Center for Zoonotic, Vector-Borne, and Enteric Diseases