19. Lathrop GM, Lalouel JM, Julier C, Ott J. Strategies for multilocus linkage analysis in humans. Proc Natl Acad Sci USA 1984; 81:3443-6.
20. Reimer RR, Clark WH Jr, Green MH, Ainsworth AM, Fraumeni JF Jr. Precursor lesions in familial melanoma: a new genetic preneoplastic syndrome. JAMA 1978; 239:744-6.
21. Antonarakis SE. Diagnosis of genetic disorders at the DNA level. N Engl J Med 1989; 320:153-63.
22. Crutcher WA, Sagebiel RW. Prevalence of dysplastic naevi in a community practice. Lancet 1984; 1:729.
23. Holly EA, Kelly JW, Shpall SN, Chiu S-H. Number of melanocytic nevi as a major risk factor for malignant melanoma. J Am Acad Dermatol 1987; 17:459-68.
24. Young JL, Percy CL, Asire AJ, eds. Surveillance epidemiology and end results: incidence and mortality data 1973-77. Bethesda, Md.: Department of Health and Human Services, 1981. (Publication no. (NIH) 81-2330.)
25. Balaban GB, Herlyn M, Clark WH Jr, Nowell PC. Karyotypic evolution in human malignant melanoma. Cancer Genet Cytogenet 1986; 19:113-22.
26. Cowan JM, Halaban R, Francke U. Cytogenetic analysis of melanocytes from premalignant nevi and melanomas. JNCI 1988; 80:1159-64.
27. Cavanee WK, Dryja TP, Phillips RA, et al. Expression of recessive alleles by chromosomal mechanisms in retinoblastoma. Nature 1983; 305:779-84.
28. Dracopoli NC, Harnett P, Bale SJ, et al. Loss of alleles from distal chromosome 1p occurs late in melanoma tumor progression. Proc Natl Acad Sci USA (in press).
29. Taylor MR, Guerry D IV, Bondi EE, et al. Lack of association between intraocular melanoma and cutaneous dysplastic nevi. Am J Ophthalmol 1984; 98:478-82.
30. Rhodes AR, Harrist TJ, Day CL, Mihm MC Jr, Fitzpatrick TB, Sober AJ. Dysplastic nevi in histologic association with 234 primary cutaneous melanomas. J Am Acad Dermatol 1983; 9:563-74.

LARGE COMMUNITY OUTBREAK OF CRYPTOSPORIDIOSIS DUE TO CONTAMINATION OF A FILTERED PUBLIC WATER SUPPLY

EDWARD B. HAYES, M.D., THOMAS D. MATTE, M.D., M.P.H., THOMAS R. O'BRIEN, M.D., M.P.H., THOMAS W. MCKINLEY, M.P.H., GARY S. LOGSDON, D.SC., P.E., JOAN B. ROSE, PH.D., BETH L.P. UNGAR, M.D., DAVID M. WORD, P.E., PAUL F. PINSKY, M.P.H., MICHAEL L. CUMMINGS, M.D., MARGARET A. WILSON, M.D., M.P.H., EARL G. LONG, PH.D., EUGENE S. HURWITZ, M.D., AND DENNIS D. JURANEK, D.V.M., M.SC.

Abstract Between January 12 and February 7, 1987, an outbreak of gastroenteritis affected an estimated 13,000 people in a county of 64,900 residents in western Georgia. Cryptosporidium oocysts were identified in the stools of 58 of 147 patients with gastroenteritis (39 percent) tested during the outbreak. Studies for bacterial, viral, and other parasitic pathogens failed to implicate any other agent. In a random telephone survey, 299 of 489 household members exposed to the public water supply (61 percent) reported gastrointestinal illness, as compared with 64 of 322 (20 percent) who were not exposed (relative risk, 3.1; 95 percent confidence interval, 2.4 to 3.9). The prevalence of IgG to cryptosporidium was significantly higher among exposed respondents to the survey who had become ill than among nonresident controls.

Cryptosporidium oocysts were identified in samples of treated public water with use of a monoclonal-antibody test. Although the sand-filtered and chlorinated water system met all regulatory-agency quality standards, suboptimal flocculation and filtration probably allowed the parasite to pass into the drinking-water supply. Low-level cryptosporidium infection in cattle in the watershed and a sewage overflow were considered as possible contributors to the contamination of the surface-water supply.

We conclude that current standards for the treatment of public water supplies may not prevent the contamination of drinking water by cryptosporidium, with consequent outbreaks of cryptosporidiosis. (N Engl J Med 1989; 320:1372-6.)

HUMAN cryptosporidiosis was first described in 1976 in a three-year-old child with no obvious immunodeficiency.[1] It was subsequently recognized as a cause of severe diarrhea in patients with the acquired immunodeficiency syndrome and found to be a common cause of sporadic and epidemic gastroenteritis in immunocompetent persons.[2-13] Transmission from calves to humans, from person to person, and by a common source have all been described.[4,8,9,12] Outbreaks have occurred in day-care centers,[10,11] among international travelers,[3,13] and in a community supplied with unfiltered drinking water from a contaminated municipal well.[9]

We report the contamination of a filtered public water supply by cryptosporidium that occurred even though the treated water met federal and state standards for drinking water and that resulted in the largest outbreak of cryptosporidiosis described to date.

From the Centers for Disease Control (E.B.H., T.D.M., T.R.O., P.F.P., M.L.C., E.G.L., E.S.H., D.D.J.) and the Georgia Department of Human Resources (T.W.M.), Atlanta; the Environmental Protection Agency, Cincinnati (G.S.L.); the University of Arizona, Tucson, Ariz. (J.B.R.); the Uniformed Services University of the Health Sciences, Bethesda, Md. (B.L.P.U.); and the Georgia Department of Natural Resources (D.M.W.) and the Morehouse School of Medicine (M.A.W.), Atlanta. Address reprint requests to Dr. Juranek at the Centers for Disease Control, Division of Parasitic Diseases (F-12), Atlanta, GA 30333.

BACKGROUND

In mid-January 1987 a college physician informed health authorities of a dramatic increase in gastroenteritis among students at West Georgia College in Carrollton, Georgia. Carrollton is the principal city in Carroll County (population, 64,900), located in western Georgia.

An initial investigation by state and federal epidemiologists indicated that the outbreak involved the entire community. The laboratory director at Carrollton's hospital reported that four stool specimens obtained from patients with acute gastroenteritis were positive for cryptosporidium. The first positive report had been on January 12.

An initial case–control study of patients presenting with gastroenteritis to the hospital emergency room and a comparison of gastroenteritis rates at nursing

The New England Journal of Medicine
Downloaded from nejm.org at CDC Public Health Library & Information Center on December 29, 2011. For personal use only. No other uses without permission.
From the NEJM Archive. Copyright © 2010 Massachusetts Medical Society. All rights reserved.

homes connected to the public water system with rates at homes independent of the system implicated the water supply as a possible source of the outbreak. An advisory to boil water was issued on January 30.

METHODS

Surveillance and Laboratory Studies

To define the course of the epidemic, we reviewed emergency-room logs at the Carrollton hospital and recorded the number of visits of patients who presented each week with acute gastrointestinal illness from December 1986 through March 1987.

From January 20 through March 10, stool specimens for ova and parasite examination were obtained from 147 patients with gastroenteritis who presented to outpatient facilities. Seventy-six of these patients completed questionnaires on their symptoms at the time of the stool collection. Two aliquots of each stool were preserved separately in 10 percent formalin and in polyvinyl alcohol. The formalin-preserved stool was examined unstained, after iodine staining, and (after concentration by formalin–ethyl acetate sedimentation) after modified acid-fast and auramine–rhodamine staining.[14] Stool preserved with polyvinyl alcohol was stained with trichrome and examined by light microscopy. All stool samples were examined at the Parasitic Disease Laboratory of the Centers for Disease Control (CDC).

To evaluate the role of bacterial or viral pathogens, we reviewed the results of all bacterial stool cultures performed at the hospital laboratory during January, and we collected stool samples from five acutely ill college students for examination by immune electron microscopy for viral particles. In addition, paired serum samples obtained six weeks apart — during the acute phase of the illness and during convalescence — from 10 college students were tested for seroconversion to rotavirus by IgG and IgA enzyme-linked immunosorbent assay (ELISA). Seven of these paired serum samples were also analyzed for the presence of antibody to Norwalk virus with use of the avidin–biotin test. Viral studies were done at the Gastroenteritis Laboratory of the CDC.

Telephone Survey

From January 31 to February 2, the Carroll County Health Department surveyed by telephone 304 households systematically sampled from the county telephone directory. Carrollton households were oversampled to ensure an adequate sample of persons who had been exposed to the public water supply.

Adult respondents (over 18 years of age) were asked about the source of their home water, their age, their sex, the place of employment of all household members, and whether any household member had been ill with abdominal pain or diarrhea since January 1. They were also asked about their consumption of specific foods, their use of restaurants, the amount of tap water they consumed, and their exposure to children in day-care centers and to farm animals. Data were obtained on all 304 respondents and 507 additional household members. County engineers determined the water supply for given work sites and schools. People whose home, school, or work site was supplied with public water were considered to have been exposed to the public water supply.

From March 7 through 12, we were able to obtain serum samples from 86 of the 159 telephone-survey respondents who were living in Carrollton and had been exposed to the public water supply. These samples and randomly selected, banked control serum samples from 20 CDC employees who had not traveled outside the United States were tested for the presence of IgG and IgM to cryptosporidium by ELISA[15] at the Uniformed Services University of the Health Sciences in Bethesda, Maryland.

Investigation of the Water System

During the outbreak, federal and local engineers evaluated the water-treatment plant in accordance with published procedures.[16] Samples of raw and treated water from various points in the water system were examined for cryptosporidium and giardia by passing 379 to 3785 liters (100 to 1000 gal) of water through a 1-μm polypropylene filter. The eluted sediment was examined directly for giardia, and a fluorescein-tagged monoclonal antibody (Meridian Diagnostics) was used to detect cryptosporidium in the sediment at the Parasitic Disease Laboratory of the CDC, according to methods described by Jakubauski,[17] and at the Department of Microbiology and Immunology of the University of Arizona, according to methods described elsewhere.[18,19]

To evaluate the means of contamination of the water supply, we reviewed data on sewage and water maintenance and on rainfall, and examined fresh stool samples for cryptosporidium from 67 of the 226 cattle (including 3 calves) pastured in the watershed.

RESULTS

Surveillance and Laboratory Studies

The number of visits of patients with gastroenteritis to the hospital emergency room increased in the second week of January, peaked from the third week of January through the first week of February, and then declined to preoutbreak levels by the last week of February (Fig. 1).

Cryptosporidium was identified in the stools of 58 of the 147 patients with gastroenteritis (39 percent) tested during the outbreak. Giardia was detected in stool from only one subject, a two-year-old child who also had cryptosporidiosis.

Of the 70 stool samples cultured for bacteria at the hospital laboratory during January, only 2 were positive: 1 for shigella and the other for campylobacter. The results of all viral studies in the 10 college students who became ill were negative.

Information on signs and symptoms was obtained from 30 outpatients with cryptosporidium-positive stools. These patients ranged in age from less than 1 year to 46 years (mean age, 20). Diarrhea (defined as three or more loose bowel movements per day) was reported by 87 percent, stomach pain by 80 percent, nausea by 67 percent, vomiting by 33 percent, fever by 30 percent, and muscle aches by 20 percent.

Telephone Survey

Of the 811 household members surveyed by telephone, 363 had been ill with diarrhea or abdominal pain since January 1. After adjustment for the oversampling of the city of Carrollton, where the attack rate was 54 percent, the overall estimated attack rate for the county was 40 percent.

Of the 489 household members who were exposed to the public water supply, 299 (61 percent) had been ill, as compared with 64 of the 322 unexposed subjects (20 percent; relative risk, 3.1; 95 percent confidence interval, 2.4 to 3.9; Taylor series approximation).[20] When we used logistic regression models to control for the exposure to the public water supply, we found no strong or significant association between illness and any other risk factor studied (i.e., exposure to day-care centers, farm animals, or particular restaurants; household size; or consumption of chicken or beef).

Among the 489 exposed household members, the attack rate was 67 percent (170 of 254) in female and 55 percent (128 of 232) in male household members (the sex of 3 subjects was not recorded) (relative risk, 1.2; 95 percent confidence interval, 1.0 to 1.4).

The New England Journal of Medicine
Downloaded from nejm.org at CDC Public Health Library & Information Center on December 29, 2011. For personal use only. No other uses without permission.
From the NEJM Archive. Copyright © 2010 Massachusetts Medical Society. All rights reserved.

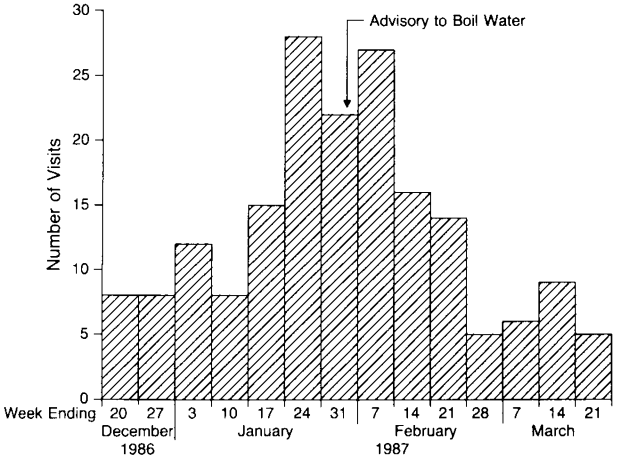

Figure 1. Numbers of Visits of Patients with Gastroenteritis to the Hospital Emergency Room in Carroll County, Georgia, According to the Week of the Visit.

Among the exposed respondents, the higher attack rate in female members remained significant when we controlled for age and water consumption. The attack rates according to age group among all 489 exposed household members ranged from 52 to 72 percent and were highest among those 20 to 29 years of age, but these differences were not statistically significant ($P>0.05$ by the chi-square test for independence).

The telephone survey indicated that approximately 50 percent of Carroll County residents, or 32,450 people, were exposed to the public water supply at home or at work. The risk of illness attributable to this exposure was 41 percent (61 percent of exposed members who became ill minus 20 percent of unexposed members who became ill). We therefore estimate that approximately 13,000 persons had an illness attributable to public-water exposure during the outbreak.

For the 86 exposed respondents to the telephone survey who provided serum samples, the prevalence of detectable IgG to cryptosporidium was higher among the 68 respondents who had become ill than among the 18 who had not become ill (76 percent vs. 56 percent; $P = 0.08$ by the chi-square test), and it was significantly higher among respondents who had become ill than among the 20 CDC employees (76 percent vs. 35 percent; $P = 0.001$ by the chi-square test). The seroprevalence of cryptosporidium-specific IgM with IgG was 12 percent in respondents who became ill, 6 percent in those who had not become ill, and 5 percent in the CDC controls ($P>0.50$, by Fisher's exact test for each comparison).

Investigation of the Water System

Roughly 7900 of the 19,000 households in the county receive water from the Carrollton water system. The remainder have wells or are connected to separate municipal water systems. The Carrollton water system draws water from a small river that runs through surrounding pasture land. The water is treated by the addition of alum, lime, and chlorine, rapid mixing, mechanical flocculation (a process to promote the aggregation of particulates), sedimentation, and rapid sand filtration.

Samples obtained from the municipal water system on January 5, 22, and 23 were tested for coliform bacteria by standard methods[21] and were all negative. All routine measurements of treated water were within the limits set by the Environmental Protection Agency and the State of Georgia for turbidity, coliform bacteria, and residual free chlorine. Nevertheless, on January 28, samples of treated water contained particles as large as 100 μm (cryptosporidium oocysts are 4 to 6 μm in size).

Cryptosporidium oocysts were ultimately identified in samples of treated water taken from the water-treatment plant on January 28, February 4, and February 5 and from four dead-end water mains, including one at the college, between February 4 and 6. Two samples of raw water obtained from streams that drain into the river above the treatment plant were positive for cryptosporidium, but five samples taken from the river itself, upstream from the treatment plant, were all negative. Three samples of treated water taken as controls from a nearby town with a separate water source were also negative.

No outbreaks of diarrheal illness were reported among cattle pastured in the county. Cryptosporidium was found in low numbers in stool samples obtained from 3 of the 56 cattle tested from pastures along the river upstream from the water plant (2 of the positive stool samples were from calves), but it was absent in the stool samples from 11 cattle tested from pastures along the streams in which cryptosporidium was found. There were no major rainfalls in early January, but more than 25 cm (10 in) of rain and snow fell from January 15 to 22.

Although no serious breaks in the water or sewage systems were reported during January, a sewage overflow caused by a blocked major sewer line was discovered in mid-February in a wooded area above the water-treatment plant. When dye was released at the overflow point, it reached the river and the water-treatment plant in approximately six hours. We could not determine when the sewage pipe had begun to overflow. An analysis of the surface-water supply for coliform bacteria after the sewage spill had been cleaned up found no indication of ongoing discharge of raw sewage.

We attributed the passage of particulates through the treatment plant to three factors. First, mechanical agitators that were scheduled for replacement had been removed from the flocculation basins in December in anticipation of the arrival of new agitators. This reduced the efficiency of the flocculation step and impaired particulate removal. Second, the efficiency of filtration was impaired by the equipment and procedures used to control the flow of water through the filters and to monitor turbidity. Finally, the filters were sometimes restarted without first being back-

The New England Journal of Medicine
Downloaded from nejm.org at CDC Public Health Library & Information Center on December 29, 2011. For personal use only. No other uses without permission.
From the NEJM Archive. Copyright © 2010 Massachusetts Medical Society. All rights reserved.

washed. This could have discharged dirt, flocculent particles, and microorganisms from the filter beds into the treated water. The Environmental Protection Agency has set a turbidity limit for water entering the distribution system of 1 nephelometric turbidity unit (NTU) or less, measured at least once daily. The Carrollton water system met this regulation; however, turbidity measurements of water obtained from individual filters on February 3 showed that three properly backwashed and restarted filters were producing water with a turbidity of 0.07 to 0.18 NTU, whereas three filters restarted without being backwashed produced water with a turbidity ranging from 0.2 to 3.2 NTU in the first three hours after they were restarted. During the first week of January the number of filters restarted without undergoing backwashing increased to 38 from a usual weekly average of 22, because water use increased after the holidays.

The water-treatment process was improved in February so that turbidity of continuously monitored treated water was 0.2 NTU or less — a value consistent with the removal of particles larger than approximately 1 μm. A sample of treated water taken on February 11 showed no oocysts. The consistently low turbidity readings resulted in the lifting of the advisory to boil water on March 2. Clinical and laboratory surveillance through the end of May showed no recurrence of cryptosporidiosis in Carroll County.

Discussion

To our knowledge, this is the first reported contamination of a filtered water system by cryptosporidium. The sudden onset of widespread gastroenteritis affecting persons of all ages is typical of a waterborne outbreak. There was a strong association of illness with exposure to the public water supply among the county residents surveyed by telephone and a high prevalence of cryptosporidium-specific IgG in exposed respondents to the survey who had been ill. Cryptosporidium oocysts were identified in the stools of patients during the outbreak as well as in the treated public water. Neither laboratory examination of patients nor evaluation of the water system yielded any evidence that other enteric pathogens contributed to the outbreak.

Although there was adequate chlorine in the water to inactivate most known bacteria and viruses,[22] cryptosporidium oocysts are highly resistant to chlorine.[23] The efficacy of boiling water to inactivate cryptosporidium is uncertain, but temperatures above 100°C kill all other protozoa that have been tested, and inactivation of cryptosporidium oocysts by exposure to a moist heat (55°C) for 20 minutes has been demonstrated. Although we have no information on the residents' compliance with the advisory to boil water, it appears, in conjunction with the improvements in water-treatment procedures, to have controlled the outbreak.

Exposed persons were defined as county residents with access to the public water supply at home, school, or work. Since Carrollton is the commercial center of the county, it is likely that a number of persons who were considered to be unexposed in our study were actually exposed to the public water supply during recreational or commercial visits to Carrollton. This may explain the illness rate of 20 percent among those considered unexposed in the study.

The higher attack rate among female residents in the survey remains unexplained. Surveys in settings with no outbreak have found a higher rate of self-reported diarrheal illness in women than in men (Ho MS: unpublished data), but our data do not allow us to determine whether the sex-based difference we observed was due to a difference in reporting behavior or susceptibility to symptomatic infection.

Cryptosporidiosis is an illness of variable severity. Many patients reported mild, nonspecific symptoms during the outbreak in Carroll County. Of those with cryptosporidiosis confirmed by stool culture, 13 percent did not have diarrhea, as defined by three or more loose stools per day; therefore, the diagnosis of cryptosporidiosis should not be excluded on the basis of the absence of diarrhea.

The prevalence of cryptosporidium-specific IgG was higher among exposed survey respondents who had not been ill than among CDC employees (56 percent vs. 35 percent) and among a group of Peace Corps volunteers tested before placement overseas (of 75 subjects, 24, or 32 percent, had IgG to cryptosporidium).[24] Although not statistically significant, these differences suggest that before the outbreak, the background exposure to cryptosporidium among residents of Carroll County was higher than the typical background exposure among U.S. residents, or that many residents had asymptomatic infection during the outbreak. Since the stool samples examined for the presence of ova and parasites from the Carrollton area were not routinely examined for cryptosporidium before November 1986, previous cases of cryptosporidiosis were not likely to have been detected.

Infected cattle in the watershed could cause long-term low-level contamination of the surface water; however, we could not conclude that the outbreak was caused directly by cryptosporidiosis in cattle, since the level of infection in cattle was low and the distribution of cattle that tested positive did not match the distribution of positive water samples.

Regardless of the source of contamination of the untreated surface-water supply, we believe that the changes in water treatment around the holiday season allowed oocysts to pass into the treated water in sufficient numbers to cause widespread illness. In addition, the sewage spill above the treatment plant and the increase in rainfall just after the onset of the outbreak may have increased the load of cryptosporidium reaching the plant, but this remains speculative.

Contamination of rivers and streams by cryptosporidium has been reported in several states.[25] The results of our investigation demonstrate that cryptosporidium can contaminate filtered public water systems

The New England Journal of Medicine
Downloaded from nejm.org at CDC Public Health Library & Information Center on December 29, 2011. For personal use only. No other uses without permission.
From the NEJM Archive. Copyright © 2010 Massachusetts Medical Society. All rights reserved.

— even when the water quality is within regulatory limits for coliform bacteria, chlorine, and turbidity — causing large epidemics of gastroenteritis in otherwise healthy persons. Further study is needed to assess the prevalence and the effect on public health of cryptosporidium in surface-water supplies and to evaluate methods of preventing future contamination of public drinking water by this hardy parasite.

We are indebted to Mr. Olan Ledford for assistance in coordinating and organizing work involving the Carroll County Health Department; to Dr. Mary Miles for bringing the outbreak to our attention and for assistance in collecting specimens and epidemiologic data; to Dr. Charles Gerba and the laboratory staff at the University of Arizona for the application of the most recent water-sampling technology; to Dr. Henry Mathews, Dr. Govinda Visvesvara, and Ms. Jennifer Dickerson, CDC, for examining the stool and water specimens; to Dr. Roger Glass and Dr. Mei-Shang Ho, CDC, for viral studies; to Dr. Bernard Nahlen, CDC, for assisting the investigation; to Mr. Lewis Mason and Mr. Jim Baxley, Carrollton City and County Water Utilities, for assistance in evaluating the water system; to Mr. Ted Mikalsen, Georgia Department of Natural Resources, for testing streams in the watershed for coliform bacteria; to Ms. Cheri Toni for help in case finding and surveillance; to Ms. Shirley Johnson for administrative assistance; to Ms. Robbie Green for notifying us of the sewage overflow; to Dr. Keith Sikes, Dr. Jeffrey Sacks, and Mr. David Smith, Georgia Department of Human Resources, for assisting the investigation; to the staffs of the college, the hospital, and the Carroll County Health Department for their assistance; and to Ms. Voughn Trader for assistance in the preparation of the manuscript.

References

1. Nime FA, Burek JD, Page DL, Holscher MA, Yardley JH. Acute enterocolitis in a human being infected with the protozoan Cryptosporidium. Gastroenterology 1976; 70:592-8.
2. Holley HP Jr, Dover C. *Cryptosporidium:* a common cause of parasitic diarrhea in otherwise healthy individuals. J Infect Dis 1986; 153:365-8.
3. Jokipii L, Jokipii AMM. Timing of symptoms and oocyst excretion in human cryptosporidiosis. N Engl J Med 1986; 315:1643-7.
4. Current WL, Reese NC, Ernst JV, Bailey WS, Heyman MB, Weinstein WM. Human cryptosporidiosis in immunocompetent and immunodeficient persons: studies of an outbreak and experimental transmission. N Engl J Med 1983; 308:1252-7.
5. Navin TR, Juranek DD. Cryptosporidiosis: clinical, epidemiologic, and parasitologic review. Rev Infect Dis 1984; 6:313-27.
6. Soave R, Armstrong D. *Cryptosporidium* and cryptosporidiosis. Rev Infect Dis 1986; 8:1012-23.
7. Fayer R, Ungar BL. Cryptosporidium spp. and cryptosporidiosis. Microbiol Rev 1986; 50:458-83.
8. Human cryptosporidiosis — Alabama. MMWR 1982; 31:252-4.
9. D'Antonio RG, Winn RE, Taylor JP, et al. A waterborne outbreak of cryptosporidiosis in normal hosts. Ann Intern Med 1985; 103:886-8.
10. Alpert G, Bell LM, Kirkpatrick CE, et al. Outbreak of cryptosporidiosis in a day-care center. Pediatrics 1986; 77:152-7.
11. Cryptosporidiosis among children attending day-care centers — Georgia, Pennsylvania, Michigan, California, New Mexico. MMWR 1984; 33:599-601.
12. Koch KL, Phillips DJ, Aber RC, Current WL. Cryptosporidiosis in hospital personnel: evidence for person-to-person transmission. Ann Intern Med 1985; 102:593-6.
13. Jokipii L, Pohjola S, Jokipii AM. Cryptosporidiosis associated with traveling and giardiasis. Gastroenterology 1985; 89:838-42.
14. Ma P, Soave R. Three-step stool examination for cryptosporidiosis in 10 homosexual men with protracted watery diarrhea. J Infect Dis 1983; 147:824-8.
15. Ungar BL, Soave R, Fayer R, Nash TE. Enzyme immunoassay detection of immunoglobulin M and G antibodies to *Cryptosporidium* in immunocompetent and immunocompromised persons. J Infect Dis 1986; 153:570-8.
16. Logsdon GS. Evaluating treatment plants for particulate contaminant removal. J Am Water Works Assoc 1987; 79(9):82-92.
17. Jakubauski W. Detection of *Giardia* cysts in drinking water: state of the art. In: Erlandsen SL, Mayer EA, eds. Giardia and giardiasis: biology, pathogenesis and epidemiology. New York: Plenum Press, 1984:263-85.
18. Rose JB. Detection of *Cryptosporidium* from wastewater and freshwater environments. Water Sci Technol 1986; 18:233.
19. Musial CE, Arrowood MJ, Sterling CR, Gerba CP. Detection of *Cryptosporidium* in water by using polypropylene cartridge filters. Appl Environ Microbiol 1987; 53:687-92.
20. Kleinbaum DG, Kupper LL, Morgenstern H. Epidemiologic research: principles and quantitative methods. Belmont, Calif.: Lifetime Learning Publications, 1982:296-9.
21. American Public Health Association, American Water Works Association, Water Pollution Control Federation, Georgia Department of Natural Resources. Standard methods for the examination of water and wastewater. 16th ed. New York: American Public Health Association, 1985.
22. Laubusch EJ. Chlorination and other disinfection processes. In: American Water Works Association. Water quality and treatment: a handbook of public water supplies. 3rd ed. New York: McGraw-Hill, 1971:201.
23. Campbell I, Tzipori AS, Hutchison G, Angus KW. Effect of disinfectants on survival of *Cryptosporidium* oocysts. Vet Rec 1982; 11:414-5.
24. Ungar BLP, Mulligan M, Nutman TB. Serologic evidence of *Cryptosporidium* infection in US volunteers before and during Peace Corps service in Africa. Arch Intern Med 1989; 149:894-7.
25. Rose JB. Occurrence and significance of *Cryptosporidium* in water. J Am Water Works Assoc 1988; 80(2):53-8.

The New England Journal of Medicine
Downloaded from nejm.org at CDC Public Health Library & Information Center on December 29, 2011. For personal use only. No other uses without permission.
From the NEJM Archive. Copyright © 2010 Massachusetts Medical Society. All rights reserved.