

Norovirus in Vermont

A Classroom Case Study

INSTRUCTOR'S VERSION

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Note: *This case study is based on a real-life outbreak investigation undertaken in Vermont in 2004.^{1,2} 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 investigations 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 expertise in epidemiology, microbiology, and environmental health. 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.

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Public Health Service
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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 recreational waters. 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 also will benefit from having familiarity with water treatment processes at swimming pool venues and evaluation of these systems but probably will rely on others with greater expertise in these areas during a real-life outbreak.

Teaching materials required: NORS Report_Norovirus Outbreak in Vermont.pdf (completed form for the National Outbreak Reporting System [CDC 52.12]).

Time required: 2.5–3 hours.

Language: English.

Level of case study: Basic Intermediate Advanced

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Learning Objectives:

After completing this case study, the student should be able to

1. list categories and examples of questions that should be asked of key informants who report a suspected infectious disease outbreak;
2. discuss considerations in working with businesses that might be identified as a possible source of an outbreak;
3. outline components of swimming pool design and operation that help prevent the transmission of pathogenic agents;
4. discuss the action of chlorine to disinfect water and factors that influence its effectiveness;
5. interpret test results for chlorine and pH with respect to swimming pool water quality;
6. identify activities that increase a person's risk for exposure to pathogens in recreational water;
7. interpret results from a cohort study, including attack rates, relative risks, and P values; and
8. describe the steps for management of fecal incidents in treated recreational water venues.

PART I. OUTBREAK DETECTION

On the morning of February 5, the mother of a young child called the Vermont Department of Health (VDH) to report a possible foodborne outbreak. The woman's child, age 5 years, and two neighborhood children, ages 7 and 10 years, had become ill with vomiting and diarrhea within 12 hours of each other. The child aged 5-years had become so sick that her mother had taken her to the emergency department at the local hospital.

Question 1: What questions (or types of questions) would you ask the mother to help determine the seriousness of this problem and the steps needed to explore the problem further?

In recording a complaint about a possible illness or outbreak, the following information should be collected:

- *WHAT is the problem (e.g., description of the illness, whether a physician was consulted, if tests were performed or treatments were provided, or whether anyone was hospitalized or died)?*
- *WHO became ill (i.e., their names, characteristics [e.g., age, sex, and occupation], and relationship to each other)?*
- *WHEN did the affected person(s) become ill (date and time of illness onset)?*
- *WHERE are the affected persons located (including addresses and telephone numbers)?*
- *WHY (and HOW) do they think they became ill (e.g., risk factors, suspected exposures and modes of transmission, and clues based on who else did and did not become ill)?*

In collecting this information, consider the following recommendations:

- 1) *Always collect as much information as possible from the person reporting the illness during the first contact because talking with that person again might become difficult. If the complainant cannot provide critical pieces of information, find out who might be able to do so. Be sure to ask the complainant how he or she can be reached and if anyone else has been notified of this problem.*
- 2) *Remember that illnesses that can be acquired through foods often can be acquired through other means (e.g., water, person-to-person contact, and animal-to-person contact). Keep an open mind about possible sources and do not assume that food is the responsible vehicle. Collect information on all possible modes of transmission. Health departments usually have a form designed for collection of exposure information on enteric diseases that covers possible food, water, person-to-person, and animal-to-person transmission.*
- 3) *If the illness is consistent with a potential foodborne illness, collect a complete food history. Regardless of the source, complainants often associate illness with the last food or meal they consumed before becoming ill, particularly if it was at a commercial establishment.*
 - *If the etiologic agent is unknown, obtain a 72-hour food history or longer (i.e., all foods/beverages/meals consumed during the 72 hours before illness onset).*
 - *For illnesses in which diarrhea is the predominant symptom (as opposed to vomiting), collect a 5-day food history because incubation periods for diarrheal diseases tend to be longer than illnesses that include only vomiting.*
 - *If the etiologic agent is known, ask about foods/beverages/meals eaten within the incubation period for that illness.*
 - *If more than one person is ill, focus on foods/beverages/meals common to all persons but still collect complete food histories for the appropriate periods for all persons.*
- 4) *Be sure to accurately record symptoms, dates and times of illness onset, and dates and times of exposures. The majority of persons who have experienced a recent illness should be able to provide you with these answers.*
- 5) *Collect and record information on pertinent negatives as well as pertinent positives. For example, if one only records that symptoms included vomiting and diarrhea, it is difficult to know if that means no fever was present or that the information was not collected.*
- 6) *Thank the person for notifying you of the problem.*

The mother reported that her child initially complained of nausea around 10:00 a.m. on Monday, February 2. The nausea was followed by vomiting and multiple episodes of diarrhea. The child was unable to eat or drink anything without vomiting. Toward evening, the child became listless. The woman took the child to the emergency department where she was noted to be dehydrated and that she had a fever. Stool and blood specimens were collected, and the child was treated with intravenous fluids and released.

The mother called the emergency department the following day to receive the test results for her child. A nurse told her that preliminary stool culture results were “negative for the usual bacteria.”

The two neighborhood children had had similar symptoms (i.e., nausea, vomiting, diarrhea, and fever) but had not become as ill as the woman's child. Their symptoms started a few hours earlier than her child's. Both had returned to school the day after becoming ill.

The three children usually did not play together but had attended a birthday party on the morning of Sunday, February 1. The mother was concerned about homemade ice cream that was served at the party because she had heard it had been prepared using raw eggs.

Question 2: What etiologic agents are consistent with the illness among the children?

Two broad classifications are used to categorize etiologies of gastrointestinal illnesses – infections and intoxications.

- *Infections are a consequence of the growth of a microorganism in the body. Illness results from two mechanisms: (1) viruses, bacteria, or parasites invade the intestinal mucosa or other tissues, multiply, and directly damage surrounding tissues; and (2) bacteria and certain viruses invade and multiply in the intestinal tract and then release toxins that damage surrounding tissues or interfere with normal organ or tissue function. The necessary growth of the microorganism (for damage to the tissues or production and release of toxins) takes time; thus, the incubation periods for infections are relatively long, often measured in terms of days, as compared with hours or minutes for intoxications. Symptoms of infection usually include diarrhea, nausea, vomiting, and abdominal cramps. Fever and an elevated white blood cell (WBC) count are often associated with infections.*
- *Intoxications are caused by ingestion of food already contaminated by toxins. Sources of toxin include certain bacteria, poisonous chemicals, and toxins existing naturally in animals, plants, or fungi. Intoxications most often result from bacteria that release toxins during growth in the food. The preformed toxin is then ingested with the food; thus, live bacteria do not need to be consumed to cause illness. Illness from a toxin manifests more rapidly than that caused by an infection because time for growth and invasion of the intestinal lining is not required. The incubation period for an intoxication is often measured in minutes or hours. Symptoms depend on the causative agent. The most common (and sometimes only) symptom of an intoxication is vomiting. Other symptoms include nausea, diarrhea, and interference with sensory and motor functions (e.g., double vision, weakness, respiratory failure, numbness, or tingling of the face). Fever and an elevated WBC count are rare with intoxications.*

The following information can help shorten the list of etiologic agents suspected during an outbreak investigation:

- *predominant symptoms (i.e., subjective complaints related to an illness [e.g., fever or nausea]) and signs (i.e., objective physical findings related to an illness [e.g., elevated temperature or vomiting]);*
- *incubation period;*
- *symptom duration;*
- *suspect exposures; and*
- *laboratory testing of stool, blood, or vomitus.*

Signs and symptoms among the three children (diarrhea and fever) are most compatible with an infection. The incubation period (approximately 24 hours if the birthday party was the source of the infection) and short duration of illness are indicative of a virus or possibly a bacterium. Given the report that the stool of one child was, as the nurse stated, “negative for the usual bacteria,” a virus might be the most likely cause of the illness. Consequently, norovirus might be foremost on the list of possible etiologic agents. (For more information about norovirus, see Appendix A.)

After confirming the mother's information with the emergency department physician, VDH staff called the mother who had organized the February 1 birthday party. The woman reported that her own child was well (except for a cold). Other parents had called her, however, saying that their children had become ill with vomiting and diarrhea.

The woman reported that her son's birthday party had occurred at a private indoor swim club in Essex, Vermont, close to Burlington. Approximately 30 children and adults were in attendance. The children ranged in age from 5 to 10 years. Not all of the children attended the same school.

Cake, ice cream, and canned drinks had been served at the party. All refreshments had been commercially prepared. The ice cream had not contained raw eggs.

The majority of children had played in the pool at the swim club before presents were opened and cake and ice cream were served. Two children who later became ill had left the party before cake and ice cream were served to attend another birthday party.

The mother provided a list of party attendees, indicating which ones she knew had been ill, and their telephone numbers. She also provided the name and telephone number for the swim club manager.

Question 3: On the basis of the information provided so far, what actions would you take? Whom would you contact? What additional information would you be interested in collecting?

Given that other persons attending the February 1 birthday party also became ill, the outbreak appears to extend beyond the three children in the initial report. We do not know, however, whether persons not included in the party are also affected.

One of the first steps that investigators should take is to contact the local/district health department. Although the state health department in Vermont is responsible for investigating outbreaks, local public health officials need to know about the problem. They might have heard of other similar cases of illness or suspicious exposures in the community. They might have knowledge of the venue where the party was held or be able to provide staff to assist in the investigation, if necessary. Contact with local public health officials also will allow for coordination of public communications about the problem.

To explore the problem further, investigators might wish to do the following:

- *Contact other party attendees to determine if they are ill and who at the party ate food or not.*
- *Collect stool specimens from ill persons for laboratory testing, including testing for norovirus. (If specimens have already been collected [e.g., the child examined at the emergency department], investigators will probably want those specimens to be forwarded to the state public health laboratory for further testing.)*
- *Contact the swim club manager to determine if others using the facility were similarly affected.*
- *Characterize ill persons by person, place, and time to provide clues on the likely source of the outbreak.*
- *Undertake hypothesis-generating interviews with a subset of patients to provide insights into the likely source.*
- *Investigate the swim club for possible sources of the outbreak.*
- *Collect samples of leftover food and drinks from the birthday party. (Note: Testing these items without a hypothesis on the source of the outbreak might not be an effective use of resources. However, collecting these items while they are still available and storing them in a manner so that they can be tested at a later time is prudent.)*

Because the majority of gastrointestinal illnesses can be spread by food, water, person-to-person contact, and animal-to-person contact, investigators will want to consider all possible sources of transmission as they begin investigating this problem.

PART II. HYPOTHESIS GENERATION

VDH investigators notified the district health department of the problem and then contacted the manager of the private swim club. The manager stated that he was dealing with a “problem” and refused to talk with health department investigators. He suggested that they leave their telephone number and he would call them back if he had time.

Question 4: How would you approach the swim club manager to gain his cooperation?

The health department likely has the right of entry to inspect the pool and the authority to require the club manager to comply with their requests for information. (The health department probably also has the authority to close the pool and revoke or suspend its operating permit.) However, the manager’s full cooperation will result in quicker responses to requests and the collection of more complete and accurate information. Developing a positive, communicative, working relationship with the manager will engender an atmosphere of cooperation and a more successful investigation.

Dealing with the club manager might be tricky at this point. To gain his cooperation, investigators should do the following:

- *state their name, credentials, and position in the health department so that the manager is clear about the source of the call;*
- *tell the manager that an investigation is in progress and that all possible sources of the outbreak, including food or person-to-person transmission, are also being considered;*
- *emphasize that the call is to confirm or eliminate suspicions about the source of the illness;*
- *explain that the investigation is not to fix blame but to identify the cause of the illness so that necessary control and prevention measures can be taken and others do not become ill;*
- *let the manager know what investigative activities are likely to occur and the benefits that can be gained from the findings (e.g., identifying needed improvements at the facility or exonerating the facility entirely);*
- *maintain an open mind and try to answer any questions the manager might have; and*
- *keep the manager informed of the progress of the investigation.*

After VDH investigators stated the reason for their call and reassured the swim club manager that the health department needed to investigate the reported illnesses so that the source could be found and actions could be taken to prevent others from becoming ill, the manager spoke with investigators.

The manager had not heard about the illnesses associated with the February 1 birthday party, but had received reports of illness among other persons who had used the pool during the weekend. Rumors were circulating that participants in the infant-mother swim class (that last met on Saturday, January 31) were sick with “stomach flu.”

The manager provided VDH investigators with the names and contact information for persons who had complained to him about being ill and for members of the infant-mother swim class.

VDH investigators, with the assistance of district health department staff, contacted households of persons who had visited the swim club and reported illness since January 27 to VDH, the mother organizing the February 1 birthday party, or the swim club manager. Investigators asked about specific symptoms, the date of illness onset, and the most recent date the ill person had visited the swim club.

On the basis of these calls, 21 persons were identified as having attended the swim club and having reported being ill (Table 1). Signs and symptoms included vomiting (90%), nausea (81%), abdominal cramps (67%), diarrhea (48%), fever (48%), and headache (43%). Symptoms began a median of 30 hours (range: 8–62 hours) after visiting the swim club.

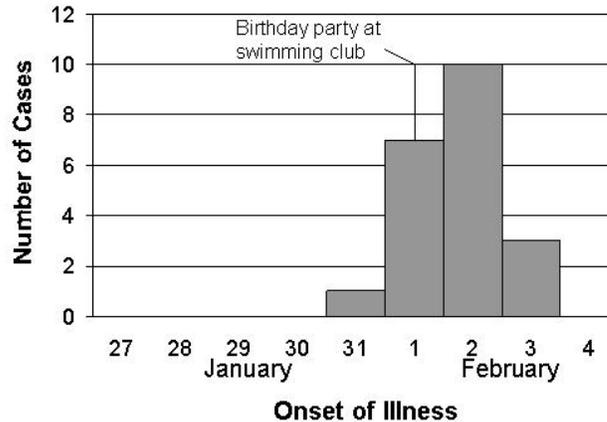
Table 1. Line list of persons becoming ill after a visit to the private swim club, Essex, Vermont, January 27–February 1.

Patient No.	Age	Sex	Signs and Symptoms*	Examined by a doctor	Date of symptom onset	Date of exposure to the pool
1	5 yrs	F	V, D, N, C, F, H	Yes	2/2	2/1 (morning)
2	7 yrs	M	V, D, N, C, H		2/1	2/1 (morning)
3	10 yrs	M	V, D, N, C, H		2/2	2/1 (morning)
4	5 mos	F	V, F		2/1	1/31 (morning)
5	1 yrs	M	V, D	Yes	1/31	1/31 (morning)
6 (mother of #5)	31 yrs	F	D, N, C, F		2/1	1/31 (morning)
7	7 yrs	M	V, N, C, H		2/1	2/1 (morning)
8	11 yrs	F	V, N, C, H		2/2	2/1 (afternoon)
9	65 yrs	M	D, N, C, H		2/2	2/1 (morning)
10	18 mos	F	V, D, N, F		2/1	1/31 (morning)
11	11 mos	F	V, D		2/2	1/31 (morning)
12	7 yrs	M	V, D, N, C, F		2/3	2/1 (morning)
13	61 yrs	F	V, D, N, C, F	Yes	2/2	2/1 (morning)
14	2 yrs	M	V, N, F		2/2	1/31 (afternoon)
15	5 yrs	M	V, N, H		2/2	2/1 (morning)
16	8 yrs	F	V, N, C, H		2/3	2/1 (morning)
17	12 yrs	F	V, N, C, H		2/1	1/31 (afternoon)
18	10 yrs	F	V, N, C, F		2/2	2/1 (morning)
19	8 mos	M	V, F	Yes	2/1	1/31 (morning)
20 (mother of #19)	22 yrs	F	V, N, C		2/3	1/31 (morning)
21	12 yrs	F	V, N, C, F		2/2	1/31 (afternoon)

*V = vomiting; D = diarrhea (defined as 3 or more loose stools in a 24-hour period); F = fever; N = nausea; C = abdominal cramps; and H = headache.

Investigators defined a case of outbreak-associated gastroenteritis as vomiting or diarrhea (i.e., three or more loose stools within a 24-hour period) in a person visiting the swim club with onset of symptoms since January 27. They plotted the cases by date of onset (Figure 1).

Figure 1. Onset of gastrointestinal illness among persons visiting a private swim club, Essex, Vermont.



Question 5: Summarize the descriptive epidemiology of cases. Do signs and symptoms among patients support your earlier suspicions about the causative agent? Were cases clustered by selected demographic characteristics? What was the time course of the outbreak?

Signs and symptoms included vomiting (90%), nausea (81%), abdominal cramps (67%), diarrhea (48%), fever (48%), and headache (43%). Symptoms began a median of 30 hours after swim club exposure. Interpretation: Signs, symptoms, and incubation period are consistent with norovirus infection.

Of the 21 case-patients interviewed, 9 (43%) were male. The median age was 7 years (range: 5 mos.–65 yrs.). Interpretation: Although we do not know the average age of all swim club visitors, the predominance of babies and children among patients indicates that the source of the outbreak might be an exposure at the club more common to these age groups.

All patients reported having visited the swim club on Saturday, January 31 or Sunday, February 1. Interpretation: January 31 and February 1 comprise the exposure period.

The first reported illness occurred on January 31 in an infant who had visited the pool that same day (perhaps a participant in the infant-mother swim class). Unfortunately, investigators did not collect time of illness onset for this child; therefore, knowing if the child was ill when taken to the pool or if the child became ill after exposure to the pool is impossible.)

The number of cases increased rapidly, peaking on February 2. The limited number of cases with onset on February 3 might be a reporting phenomenon (i.e., the ill persons had not had the time to notify anyone). Interpretation: If the decline in cases on February 3 is real, the pattern of illness onset among patients indicates a common source exposure of limited duration.

During the calls, multiple parents, who had been at the pool on January 31 noted that the water in the pool had been cloudy. One parent had reported the pool's condition to the lifeguard and was told that the cloudiness resulted from chemicals added to the water. The parent later saw another swim club staff member collecting water from the pool for testing. No one reported having seen a fecal incident or vomiting while they were at the pool.

On the basis of the initial findings, VDH investigators believed that the gastrointestinal illness was consistent with norovirus infection. They hypothesized that the virus was spread by exposure to the pool at the private swim club on Saturday, January 31, or Sunday, February 1. The district health department arranged collection of stool specimens from 10 patients for norovirus testing at the Centers for Disease Control and Prevention (CDC), using reverse transcription-polymerase chain reaction (RT-PCR).

Question 6: What studies or investigations would you undertake to explore the hypothesis that exposure to the pool at the private swim club was the source of the outbreak?

The following are reasonable next steps in this investigation:

- *Undertake an environmental health assessment of the private swim club including the pool, operating policies and procedures, and surrounding facilities.*
- *Undertake an epidemiologic study (e.g., cohort or case-control study) to test the hypothesis regarding the outbreak source and risk factors for infection such as exposures to water, food, drinks, and fomites (e.g., shared toilets, shower, or locker rooms). Because norovirus can be spread by both stool and vomitus, investigators should make a concerted effort to identify fecal incidents and vomiting events at the pool.*

PART III. ENVIRONMENTAL STUDIES AND WATER QUALITY INVESTIGATION

On the afternoon of February 5, VDH environmental health investigators undertook a comprehensive evaluation of the private swim club associated with the gastroenteritis outbreak. Investigators met with the swim club manager, the pool operator, and staff on duty during the outbreak period.

The goal of the evaluation was to gain a thorough understanding of the design features of the swim club and its operations so that investigators could explore the suspected source of the outbreak and assess factors that might have contributed to its occurrence.

Question 7: What swimming pool design features, operations, and policies typically prevent or reduce contamination of pool water or exposure of bathers to potentially harmful pathogens?

Note: *Students should think broadly about this question and consider efforts in addition to the obvious need to filter and chlorinate water. Instructor might want to divide the class into four or five groups, with each group being given one of the following headings as a focus.*

Pool Design

- *Design of pool and equipment (including the water treatment system) so that it accommodates the size and desired use of the pool*
- *Separate recirculation and treatment of water from different pools (e.g., lap pools, wading pools, and hot tubs) to prevent cross-contamination*
- *Design of surrounding area so that non-pool water does not enter pool*
- *Provision of bathroom facilities to minimize the likelihood of urination or defecation in the pool and to promote bather hygiene (e.g., showers, readily available toilets, diaper-changing stations away from the poolside, and hand-washing facilities)*
- *Fencing of outdoor pools to prevent animals from entering pool and surrounding area*

Water treatment

- *Removal of debris on the water surface and from skimmers*
- *Brushing and vacuuming of pool surfaces (walls, floors, and decks) and use of algaecides to prevent algae or biofilm growth (slime)*
- *Continuous recirculation and treatment of water in pool (e.g., hair and lint strainer followed by filtration, addition of disinfectant, and adjustment of the pH) at a rate appropriate for pool use (see Question 8 for discussion of turnover rate)*
- *Use of automatic chemical feeders to ensure the uniform, continuous addition of chemicals needed for water treatment*
- *Use of supplementary disinfection systems (e.g., ultraviolet [UV] or ozone)*
- *Balance of pool chemistry (organic content, pH, total alkalinity, calcium hardness, temperature, and total dissolved solids) to stabilize the amount of free chlorine residual in pool and its effectiveness*
- *Superchlorination of pool water if a fecal incident occurs or if other special conditions are met*
- *Changing pool water treatment to fit conditions (e.g., excessive evaporation, addition of rain water to pool, or higher than normal bather loads)*
- *Routine maintenance of pumps, filters, and other equipment according to manufacturer specifications*
- *Maintaining records of equipment maintenance*
- *Requirements for certification of pool operator (and required knowledge of necessary treatments)*

Policies to prevent introduction of pathogens

- Designation of bather load limits that are consistent with the pool design and water treatment parameters
- Requirements that bathers shower thoroughly before entering pool
- Policies that exclude bathers from the pool with skin cuts; blisters; open sores; inflamed eyes; any infection of the eyes, ears, nose, or throat; or gastrointestinal illnesses
- Requirements that infants and toddlers use swim diapers
- Education of bathers about correct pool use and bather hygiene (e.g., no swimming when ill with diarrhea, showering before entering pool, and encouraging parents to take children to the bathroom intermittently)
- Policies that exclude animals from the pool and the surrounding area
- Policies for handling staff who have illnesses that can be spread through water

Efforts to prevent exposure of bathers to contaminants in pool (other than water treatment)

- Adequate sanitation of entire pool complex (e.g., pool deck, toilets, diaper-changing areas, and locker rooms)
- Education discouraging bathers from swallowing pool water
- Policies prohibiting eating or drinking around pool area
- Policies for response (i.e., disinfection guidelines) to fecal incidents, vomiting, and body fluid spills

Monitoring to detect and correct pool problems

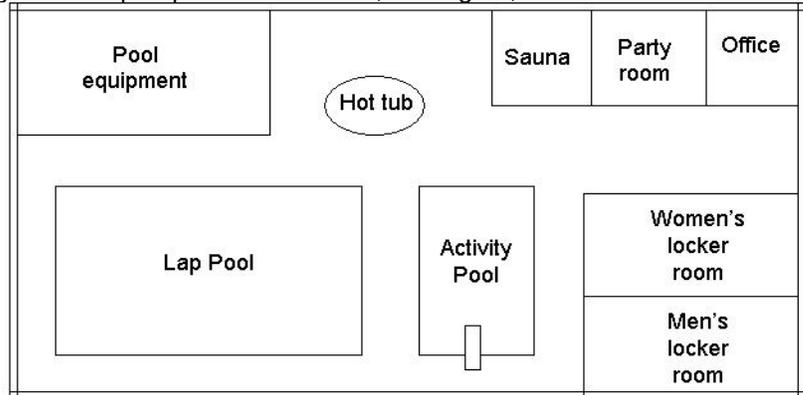
- Routine monitoring of water appearance
- Routine monitoring of water chemistry (e.g., chlorine [i.e., free, combined, and total], organic content, pH, total alkalinity, calcium hardness, temperature, and total dissolved solids)
- Keeping records of water chemistries (facilitates detection of trends)
- Policies for responses to abnormal pool chemistries
- Training of pool personnel on proper pool operations and policies
- Clear lines of communication between pool maintenance staff and those making decisions about responses

At the end of the discussion, students should be encouraged to review “Swimming Pool Venue Environmental Health Outbreak Investigation Survey: An Environmental Health Systems Approach to Recreational Water Illness Prevention” available at <http://www.cdc.gov/healthywater/office/emergency/environmental-health-outbreak-survey-swimming-pool.doc> to understand areas of focus when investigating a pool in response to a waterborne outbreak.

VDH environmental health investigators learned the following information about the swim club and its operations. The club actually had two indoor swimming pools: a smaller activity pool and a lap pool. The smaller activity pool had been used for the February 1 birthday party and the infant-mother swimming class. The club also had a hot tub, men’s and women’s locker rooms, a sauna, and a party room where food was served for private events (Figure 2).

The lap pool, activity pool, and hot tub were situated close to each other (Figure 2). The men's and women's locker rooms were adjacent to the pools. Each locker room had a diaper-changing station. Hand-washing signs were posted throughout the club.

Figure 2. Map of private swim club, Burlington, Vermont.



The swim club was popular for children's parties because the activity pool had a slide. Swim classes were also held at the club; classes for children and infants-mothers were held in the activity pool. The club did not have a snack bar. Food for private parties was brought in by event organizers. Pool staff did not help prepare or distribute food for these special events.

Municipal public water was used to fill the pools. The water in the three pools circulated separately for treatment, moving first through a hair and lint strainer (where the larger debris in the water was removed) and then to a pump. From the pump, the water was forced through a rapid sand filter, where it was then disinfected. After disinfection, the water was heated and returned to the pool through a series of inlets in the pool wall.

Water recirculated continuously in all three pools. State law required turnover rates of 6 hours for the lap pool, 2 hours for the activity pool, and 1 hour for the hot tub. Flow meters measured the flow rate for filtration of the water from each pool.

Question 8: What is a turnover rate? Why is the desired turnover rate different for different types of pools?

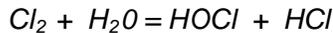
The turnover rate is the amount of time used for the net volume of water in a pool to be circulated through the pump and filter system for treatment. If the volume of the pool is circulated 2 times/day, then the turnover rate is 12 hours. If the volume is circulated 4 times/day, then the turnover rate is 6 hours.

The desirable turnover rate depends on the size, type, and volume of the pool. The recommended turnover rate for the typical public swimming pool is 6–8 hours. Because of the increased chance of fecal incidents among young children or leaky diapers, the recommended turnover rate for wading pools is shorter (usually 1–2 hours). The recommended turnover rate for hot tubs and spas is even shorter (usually less than an hour) because the higher water temperature results in more organic wastes being released into the water (e.g., bather sweat, sloughing of dead skin cells, and removal of dirt through the scrubbing action of the water jets) and accelerated bacterial growth. Spas also usually have higher bather loads per water volume than pools.

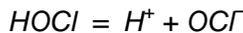
Liquid sodium hypochlorite was used to disinfect the pools at the swim club. An automated disinfectant feeder was attached to the filtration system, helping to mix the disinfectant with the water. A device operating in conjunction with the disinfectant feeder automatically adjusted the pH of filtered and chlorinated water.

Question 9: How does chlorine act to disinfect water? What factors influence the effectiveness of chlorine as a pool disinfectant?

When chemicals containing chlorine (Cl_2) are added to pool water, hypochlorous acid (HOCl) and hydrochloric acid (HCl) form as follows:



The hypochlorous acid can dissociate into hydrogen ions (H^+) and hypochlorite ions (OCl^-):



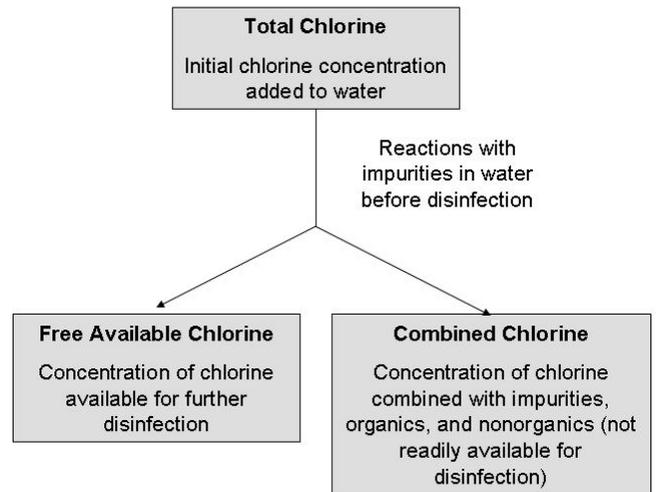
Chlorine is a powerful oxidizing agent and acts as a disinfectant to destroy such harmful organisms as bacteria, algae, fungi, and viruses by destroying cellular enzymes, structures, and processes. HOCl is the most effective form of chlorine to disinfect water because it easily penetrates into and kills bacterial cells. In contrast, OCl^- is a relatively poor disinfectant because of its inability to penetrate into the bacterial cell.

(Note: Although sodium and calcium hypochlorite were common pool disinfectants at the time of this outbreak, chlorinated cyanurates are being used more frequently now because chlorine in the presence of cyanuric acid dissipates more slowly in the presence of sunlight and provides a more stable and longer lasting chlorine residual than that provided by hypochlorite forms.)

When chlorine-based chemicals are added to pool water, they react with impurities (including microorganisms), organic compounds, and nonorganic compounds (primarily ammonia from bather sweat and urine). The portion of chlorine that reacts with these impurities and compounds is called the combined chlorine and is not readily available for disinfection. (The chlorine that reacts with ammonia forms chloramines. Chloramines are the source of chlorine-related odors and eye and respiratory irritation from pool water.) The portion of chlorine that remains uncombined (as HOCl) is referred to as the free available chlorine (or chlorine residual). Free available chlorine can kill harmful microorganisms.

The sum of free available chlorine plus combined chlorine is the total chlorine. Free available chlorine and combined chlorine levels are important measures of pool water quality and operation.

Figure A. Chlorine reactivity in water.
(INSTRUCTOR VERSION ONLY)



The effectiveness of chlorination as a disinfectant depends on five key factors, as follows:

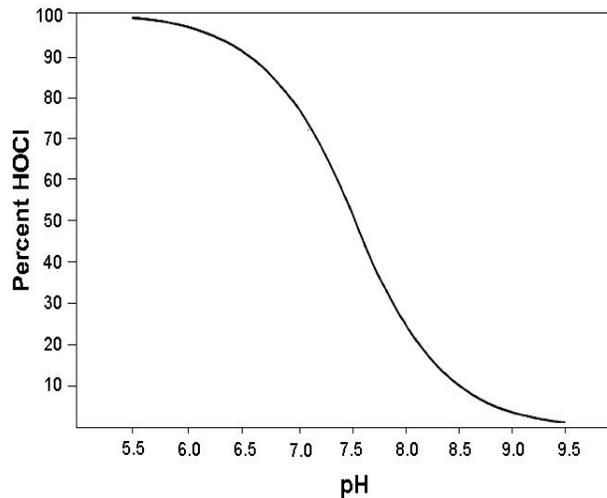
1. **Concentration** – Disinfection is directly related to the concentration of HOCl. The higher the concentration of HOCl in the water, the more effective the disinfection.
2. **Contact time** – Destruction of organisms is directly related to the contact time with the chlorine. Provided other conditions remain constant, if the contact time increases, the concentration needed to achieve the same microorganism kill decreases; as the concentration increases, the contact time decreases.
3. **pH** – pH strongly influences the ratio of HOCl to OCl⁻. A low pH favors formation of HOCl and a high pH favors formation of OCl⁻ (Table A and Figure B). For swimmers' comfort, the pH should be near the neutral range of 7.2–7.6. (The pH of our eyes is 7.2.)

Table A. Effect of pH on hypochlorous acid (HOCl) concentrations.
(INSTRUCTOR VERSION ONLY)

pH	Free chlorine available as HOCl
6.5	90%
7.0	73%
7.5	56%
8.0	21%
8.5	10%

Source: De Haan W, Johanningsmeier JS. *Swimming pool pest management: a training manual for commercial pesticide applicators and swimming pool operators*. Lansing, MI: Michigan State University Extension Pesticide Education Program Office.

Figure B. Percentage of chlorine in the form of hypochlorous acid (HOCl) at varying pH. (INSTRUCTOR VERSION ONLY)



Source: Centers for Disease Control (CDC). *Swimming pools. Safety and disease control through proper design and operation*. Atlanta, GA: US Department of Health and Human Services (CDC); 1976; HHS Publication No. (CDC) 88-8319.

4. **Temperature** – An increase in temperature accelerates the rate of chemical reactions, which accelerates the disinfection process.
5. **Other substances in the water** – Impurities, organic materials, and inorganic materials (e.g., ammonia) react with chlorine. After chlorine combines with other substances, it is no longer available to disinfect impurities in the pool or is less effective as a disinfectant (as is the case of chloramines).

In addition, not all types of organisms react to chlorination in the same way. For example, the majority of bacteria are more susceptible to chlorine than viruses, and the majority of viruses are more susceptible to chlorine than protozoa. Among protozoa, *Giardia* is more susceptible than *Cryptosporidium*, which is highly resistant to chlorination.

Note: The level of susceptibility of a microorganism to chlorination can be described through the CT factor (concentration times time). The CT factor is the product of the chlorine concentration (in mg/L) and the time (in minutes) that the microorganism must be in contact with that chlorine concentration to inactivate a certain percentage of the microorganism. The CT factor is a constant. As the concentration of chlorine increases, the necessary time decreases and vice versa.

Pool operations at the private swim club were performed by lifeguards. However, they received no standardized training or certification in pool maintenance but took instructions from the pool operator who serviced the pool equipment and made decisions regarding water treatment. Staff reported that they tested the water from each pool twice daily; but no records of the results were maintained.

Question 10: What tests are routinely performed on pool water to determine its safety for bathers? How would you collect water samples from a swimming pool for these tests?

Water testing is an essential part of swimming pool operations and maintenance because the concentrations of various chemicals in the pool constantly change as a result of the following factors:

- *Chemicals are added for pool maintenance or from the bathers themselves.*
- *Chemical reactions are occurring.*
- *Water evaporates from or is splashed out of the pool.*

To ensure that the water is safe for swimming, the chlorine level and pH should be tested routinely. Chlorine measurements include the free available chlorine (available to disinfect the pool water) and the total chlorine. (Combined chlorine is calculated by subtracting the free available chlorine from the total chlorine.) The frequency of testing for chlorine and pH depends on the type of pool, its usage, and environmental conditions, but should, at a minimum, occur several times a day, particularly during heavy use. Even if the pool has an automatic chemical control system, these systems can be out of calibration, and regular testing of the water still is essential.

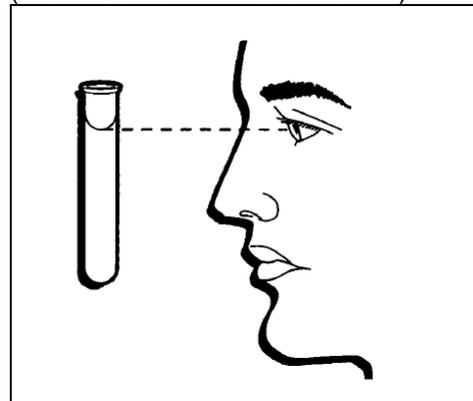
Multiple other tests are also conducted (e.g., total hardness, total alkalinity, and total dissolved solids) but are performed intermittently after pool chemistry stabilizes.

Different test kits are commercially available for testing the chlorine level and pH.

Regardless of the kit used, certain basic rules should be followed when testing pool water.

1. *Test at times when the pool is used to capacity or during peak periods of use.*
2. *Rinse the testing tube with pool water before collecting the sample.*
3. *Ensure that the sample is representative of the pool water. Collect the sample from a location that contains well-mixed pool water and is at least 12inches below the water's surface. Do not collect the sample from an area adjacent to a pool water inlet because it is returning recently chlorinated water.*
4. *Add the water sample to the tube until the bottom of the curved-upper surface (called the meniscus) is even with the prescribed level. Have the fill line at eye level when filling the sample container (Figure C).*
5. *Only use reagents provided with the test kit.*

Figure C. Reading water level in testing tube.
(INSTRUCTOR VERSION ONLY)



From: De Haan W, Johanningsmeier JS. Swimming pool pest management: a training manual for commercial pesticide applicators and swimming pool operators. Lansing, MI: Michigan State University Extension Pesticide Education Program Office

6. *When mixing the test reagents, never place the thumb or finger over the tube opening. Use the caps provided to prevent contamination. Briefly shake or gently stir the sample to dissolve the reagent.*
7. *Read the sample within the prescribed time. The majority of commercial pool test kits are colorimetric (i.e., the concentration of the chemical is determined by comparing the intensity of the color of the sample being tested and the intensity of color of a control sample against a color wheel).*
8. *Rinse all testing tubes, stirring rods, and equipment thoroughly after each use, both inside and outside. Do not rinse droppers or reagent bottles or let the droppers touch pool water. Rinse the droppers only with a small amount of the reagent with which they are associated. Do not handle the equipment or reagents with dirty hands.*

Because no records of water chemistry were maintained at the swim club, aquatic staff were asked to recall water conditions during the weekend and the quantity, time, and type of chemical solutions they had added to each pool. Staff were also asked about any unusual occurrences (e.g., fecal incidents, vomiting, or deviations from normal operating procedures).

On Friday, January 30, no abnormalities in pool water appearance were noted by staff, and testing of water from all three pools was reported as being “normal”. Staff had reported a marked cloudiness of the water in the activity pool on Saturday and that patrons had complained about the cloudiness. No action was taken, despite complaints from patrons concerning water quality, because the pool operator was off-duty.

The cloudiness of the activity pool persisted through Sunday morning, February 1. Chlorine and pH readings taken by staff at that time were “below acceptable standards.” The pool operator was called, and staff were instructed to superchlorinate the pool with several cups of 65% calcium hypochlorite granules.

On Monday morning, the pool operator returned to duty at the swim club and tested a water sample from the activity pool. The sample revealed a total chlorine of 1.5 parts per million (ppm), a free available chlorine of 0.5 ppm, and a pH of 6.8.

Question 11: Interpret these test results.

Health codes of the jurisdiction in which the pool is located should be checked for local requirements. The CDC recommends maintaining the free available chlorine level in a swimming pool at 1–3 parts ppm and the pH at 7.2–7.8.

The combined chlorine is also important in pool maintenance. (High combined chlorine reflects high chloramine levels, which lead to a chlorine odor of the pool and eye and respiratory irritation.) Remembering that the combined chlorine is the total chlorine minus the free available chlorine, the combined chlorine is:

$$1.5 \text{ ppm (total)} - 0.5 \text{ ppm (free available)} = 1 \text{ ppm (combined)}$$

Although the CDC does not publish recommendations for combined chlorine, the majority of pool codes recommend limiting this level to ≤ 0.5 ppm. (Eyes begin to burn at levels above 0.4 ppm.)

Testing of the activity pool at the private swim club indicates that free available chlorine and pH levels were below the recommended safe levels and the combined chlorine was high. Chlorine must be added to the pool to raise the free available chlorine level and remove chloramines in a process called breakpoint chlorination.

Note: *The amount of chlorine that should be added is beyond the scope of this case study. However, students might wish to consider this problem. Please see Appendix B for further details.*

Upon his return to the swim club, the pool operator found a kink in the chemical feed pump tube that supplied sodium hypochlorite to the activity pool water. The kink was repaired and the pool was superchlorinated again Monday night (February 2). The pool operator reported that the chlorine and pH were within normal limits when tested Tuesday morning, February 3. These findings were confirmed by VDH investigators.

The swim club did not have standard operating procedures detailing how to respond to abnormal pool chemistries; how to handle water quality complaints; or how to respond to fecal incidents, vomiting, or problems when the pool operator was off-duty. Because aquatic staff turnover at the pool was high, the swim club manager believed that the pool operator should make decisions about pool problems on a case-by-case basis.

PART IV. EPIDEMIOLOGIC STUDY TO TEST THE HYPOTHESIS

After the environmental health assessment of the private swim club, VDH investigators conducted an epidemiologic study to confirm suspicions regarding the source of the outbreak and to identify risk factors for infection.

The swim club manager estimated that 250 persons had visited the club from Friday, January 30–Monday, February 2. Pool attendance records and contact information were available for swim club members. The club manager also provided contact names for group events held at the pool during this time period.

VDH investigators decided to undertake a cohort study because the outbreak was confined to a well-defined group of persons (i.e., those individuals who had visited the pool during January 30–February 2) and the exposure of interest was known. A cohort study also permitted investigators to identify all cases and calculate attack rates.

Investigators planned to contact swim club members who had been at the club during the outbreak period and persons who had attended the special events during that weekend. Each person (or his or her parent) was to be asked about recent gastrointestinal illnesses; onset of symptoms; specific swimming pool exposures; food and water consumption while at the swim club; use of locker rooms, showers, and toilets; and whether they witnessed anyone vomiting or any fecal incidents at the pool. A VDH epidemiologist developed a questionnaire to collect the information.

Question 12: What activities might increase one's risk for exposure to pathogens in swimming pool water and, therefore, be of interest in this cohort study?

Activities that might increase one's risk for exposure to pathogens in swimming pool water include

- *going into the swimming pool,*
- *getting water in the mouth or swallowing water,*
- *putting the head under water,*
- *diving into the water,*
- *using pool play equipment (e.g., slide or swing rope) that increases the risk for water ingestion,*
- *having water splashed in the face, and*
- *amount of time in the pool.*

The date and time a person was in the pool (in relation to when the pool was thought to have the highest level of contamination) also affects exposure to pathogens in the swimming pool.

The exposure questions used in the cohort study are included in Appendix C. Because norovirus can be spread in multiple ways (e.g., vomiting; fecal incidents; fomites such as locker room surfaces, showers, and toilets; contaminated food; and contaminated water), investigators ensured that these exposures were included in the questionnaire.

VDH and district health department staff members were trained to administer the questionnaire by telephone for the cohort study. Interviews were conducted during February 12–22. Information was collected for 189 (74%) of the 255 persons who had visited the swim club during the period of interest.

A case was defined as vomiting or diarrhea (i.e., three or more loose stools within a 24-hour period) in a person who had gone to the swim club during the outbreak period and who experienced symptoms within 72 hours of visiting the facility. Investigators calculated attack rates and relative risks for different exposures at the club and set a P value of 0.05 as the cut-off for statistical significance.

Fifty-two (33%) of the 160 persons who either swam in or accompanied children who swam in the activity pool met the case definition. Only one (4%) of the 28 persons who only used other parts of the facility (e.g., lap pool, hot tub, or locker rooms) met the case definition. Because of these findings, further analyses were restricted to the 157 persons who either swam in or accompanied children who swam in the activity pool and who provided investigators complete information.

Attack rates were 0% (0/21) for persons who used the activity pool on January 30; 57% (25/44) for persons who used the pool on January 31; 29% (22/75) for persons who used the pool on February 1; and 12% (2/17) for persons who used the pool on February 2. Six persons, including three who were ill, had exposures to the pool on multiple days. Attack rates also varied by other exposures in and around the activity pool (Table 2).

Table 2. Illness among persons who attended the private swim club by exposure, Vermont, January 30–February 2.

Exposure	Exposed ill	Exposed well	Exposed attack rate	Not exposed ill	Not exposed well	Not exposed attack rate	Relative risk	P value
Sex male	34	50	40%	18	55	25%	1.6	0.05
Went into the activity pool	48	79	38%	2	28	7%	5.4	0.002
Got water in mouth*	39	41	49%	9	37	20%	2.5	0.002
Swam*	42	71	37%	4	10	29%	1.3	0.8
Got splashed in face*	52	40	57%	0	35	0	Undefined**	0.0000
Used slide*	24	38	39%	24	31	44%	0.9	0.7
Ate at facility	16	11	59%	36	94	28%	2.1	0.003
Drank at facility	17	15	53%	35	90	28%	1.9	0.01
Ate or drank at facility	18	14	56%	34	91	27%	2.1	0.004
Used locker room	50	94	35%	2	11	15%	2.3	0.3
Used shower facilities	14	35	29%	38	70	35%	0.8	0.5

*Pool behaviors assessed only among the 127 persons who went into the activity pool.

**Relative risk not calculable because all ill persons had the exposure (i.e., the attack rate among persons not splashed in the face was zero).

Question 13: Interpret the results from the cohort study presented in Table 2.

Relative risk is the standard measure of association for a cohort study. It tells us how much more likely (or less likely) it is for persons exposed to a factor to experience an illness, compared with persons not exposed to the factor.

A relative risk of

- *1.0 (or close to 1.0) means the risk for illness is similar among the exposed and unexposed group and exposure is not associated with illness;*
- *Greater than 1.0 means the risk for illness is greater among the exposed than the unexposed group and the exposure might be a risk factor for the illness; and*
- *Less than 1.0 means the risk for illness is less among the exposed group than the unexposed group and the exposure might be a protective factor.*

The attack rates by day (with no cases among persons swimming only on January 30 and the highest attack rates among persons swimming only on January 31) provide evidence that the pool was contaminated on the morning of January 31 (i.e., the date of the infant-mother swimming class).

Males were 1.6 times more likely to become ill than females. Persons who went into the pool were 5 times more likely to become ill than those who did not. Among those who went into the pool, persons who got water in their mouths were 2.5 times more likely to become ill than those who did not. Persons who got splashed in the face were also more likely to become ill than those who did not; however, the relative risk was not calculable because all ill persons reported being splashed in the face. In addition, persons who ate or drank while at the facility were approximately 2 times more likely to become ill than those who did not. These findings were statistically significant at a P value of 0.05 (i.e., a 5 in 100 probability of being the result of chance alone).

Students interested in learning how to calculate attack rates and relative risks should review Appendix D.

In the cohort study, going into the activity pool at the private swim club was significantly associated with illness. Among persons who went into the activity pool, getting water in the mouth and getting splashed in the face were significantly associated with illness. Neither swimming (versus wading) nor using the slide was associated with illness.

Use of the locker rooms or showers at the swim club was not significantly associated with illness. However, eating and drinking at the swim club were significantly associated with illness.

Question 14: (OPTIONAL) The relative risks for eating and drinking at the swim club were greater than 1.0. The findings were statistically significant. Do you think eating and drinking at the swim club were risk factors for illness? How would you explore these findings?

Attack rates among persons who ate or drank while at the pool were higher than those among persons who did not. A closer look at the data provides clues about the significance of these exposures.

- *Only 18 (35%) of the 52 ill persons either ate or drank something at the swim club; therefore, these exposures (if risk factors) might account for only a limited number of the cases.*
- *The swim club did not have a snack bar, and food or drink brought into the facility was for special parties or events.*

- *Persons attending parties or events at the swim club might have differed from other persons using the swim club (e.g., date of exposure to the pool, characteristics or behaviors that increased their risk for infection, including getting water in the mouth or getting splashed with water).*
- *The risk for developing illness varied by date of exposure to the pool.*

These considerations put the association between illness and eating or drinking something at the swim club in question. A stratified analysis (or logistic regression) can help determine if eating or drinking at the swim club were independent risk factors for illness or confounders for a true risk factor (e.g., date of exposure to the pool or increased likelihood of getting water in the mouth, which is more likely among younger children).

Eating and drinking at the facility accounted for only 18 (35%) of the 52 cases of gastrointestinal illness. Furthermore, investigators noted that persons who ate and drank at the facility were largely limited to children attending the birthday party on the morning of February 1, when the water in the activity pool was highly suspect in terms of maintenance failures and contamination.

When analyses were stratified by date of exposure to the swim club, persons eating at the facility or drinking at the facility were at no greater risk for illness than other persons attending the club on the same day. In addition, multivariate logistic regression analysis identified the date of attendance at the facility and getting water in the mouth were the only factors significantly associated with illness. Investigators concluded that food and drinks were not independent risk factors for illness.

PART V. CONTROL AND PREVENTION MEASURES

The cohort study confirmed suspicions that the outbreak was spread by exposure to water in the activity pool at the private swim club and likely resulted from a fecal incident in the pool when the chlorinator was not functioning properly. (For a summary of the investigation, see *Norovirus Outbreak in Vermont.pdf*.)

Five of 10 stool specimens collected from ill persons and submitted to CDC tested positive for norovirus by RT-PCR testing. The nucleotide sequences of the amplified RT-PCR products were identical, indicating a single contamination event at the activity pool.

The chlorinator was fixed and, at the time of the pool evaluation, pool chlorine and pH were consistent with recommended national standards.

Question 15: What other interventions might be necessary for preventing future outbreaks?

This outbreak was the consequence of multiple system failures – failure to maintain the pool correctly, failure to have personnel adequately trained, and failure to have policies and procedures in place when a problem is recognized. Without correction of these problems, the private swim club is at high risk for future waterborne diseases and outbreaks.

Although fixing the chlorinator for the activity pool will correct the immediate problem, to prevent the problem (or a similar problem) from recurring, multiple changes are needed at the swim club.

Recommended changes include

- *training pool staff in water testing and interpretation;*
- *keeping records of pool chemistry testing;*
- *keeping records of pool equipment maintenance;*
- *having the pool operator onsite or available for consultation, particularly on weekends when pool usage is highest;*
- *developing standard operating procedures and emergency response plans for water problems;*
- *developing clear lines of communication between personnel;*
- *educating pool users about necessary pool hygiene and ways to avoid fecal incidents and urination in the pool; and*
- *institution of a preventive maintenance program to replace common equipment parts before failure.*

VDH investigators believed that a lack of pool staff training, inadequate record-keeping, and lack of standard operating procedures contributed to the outbreak. Consequently, VDH investigators recommended that all pool staff at the club be trained in water testing and basic pool maintenance and that the pool operator remain onsite or be readily available for consultation during weekends, when pool usage was usually highest. Investigators also recommended that the club keep records of routine pool chemistries and pool maintenance.

In addition, investigators recommended that the swim club develop written standard operating procedures and emergency response plans detailing how water-quality complaints should be handled, the correct response, and lines of communication to the pool operator. In particular, VDH investigators recommended the development of a fecal incident response policy.

Question 16: (OPTIONAL) Study the standard CDC recommendations for a fecal incident response in Appendix E. Formed stools are treated differently from diarrheal stools in the response to a fecal incident. How do the responses differ and why?

With the majority of infectious diarrheal illnesses, the number of pathogens contained in each bowel movement decreases as the diarrhea stops and the person's bowel movements return to normal. Therefore, a formed stool will likely contain fewer pathogens than a diarrheal stool. Furthermore, if a formed stool contains pathogens, the pathogens are less likely to be released into the pool because they are mostly contained within the stool. Finally, studies indicate that formed fecal incidents are less likely to contain Cryptosporidium, a protozoan that is highly resistant to chlorine levels commonly used in pools. However, formed stools can contain Giardia.

Because a diarrheal fecal incident is considered to be a higher-risk event than a formed fecal incident and might contain the relatively chlorine-resistant Cryptosporidium, the response to a fecal incident differs, depending on the form of the stool.

- *For formed stool, the pool is closed immediately and the stool is removed. The free available chlorine level is raised to 2 ppm* (assuming a pH of 7.2–7.5 and a water temperature of 77°F [25°C]). At this chlorine concentration, the pool remains closed for 25 minutes. (If the chlorine concentration varies from this level, the contact time will also vary.)*
- *For diarrheal stool, the pool is closed immediately and as much of the fecal matter is removed as possible. The free chlorine level is then raised to 20 ppm** (assuming a pH of 7.2–7.5 and a water temperature of 77°F [25°C]). At this chlorine level the pool remains closed for 12.75 hours. (If the chlorine concentration varies from this level, the contact time will also vary.) For a diarrheal stool, the filter is also thoroughly backwashed after the pool has been at the desired chlorine level for the desired time. The backwash effluent is discharged directly to waste in accordance with state or local regulations.*

**This chlorine concentration and closure time is based on 99.9% inactivation of Giardia cysts at pH 7.5, 77°F (25°C).*

***This chlorine concentration and closure time is based on 99.9% inactivation of Cryptosporidium oocysts at pH 7.5, 77°F (25°C).*

VDH investigators helped the swim club manager and pool operator develop a written policy for responding to fecal incidents. As part of the policy, staff were to document each fecal incident by recording the date and time of the event, whether it involved a formed or diarrheal stool, and the free chlorine levels and pH at the time the event was detected.

Pool management distributed the fecal incident response policy to all swim club staff and held special classes to review the approach to a fecal incident. New staff members received the policy and viewed a short video about the steps necessary to respond to a fecal incident.

After the investigation, members of the private swim club voiced concern about the adequacy of actions taken to prevent future waterborne outbreaks at the club. The club manager asked VDH staff to meet with interested club members.

Question 17: What information would you share with swim club members and other patrons?

As a result of the environmental health assessment of the pool and the cohort study, swim club members will be aware of the outbreak and investigation and be concerned about the pool safety. A meeting with club members will provide an opportunity for health department staff to describe the outbreak, outline the investigation and results, and summarize control measures. More importantly, the meeting can be used to highlight the critical role that the public plays in maintaining pool safety and the steps swim club members and other patrons can take to ensure safe pool water.

The following advice should be shared with swim club members. This information should also be included in signage around the swim club, placed conspicuously, and possibly with materials distributed to club members as they pay their membership fees.

- *Do not to swim if you have diarrhea.*
- *Do not to swallow pool water.*
- *Shower thoroughly, washing the perianal surface, in particular, before entering the pool.*
- *Wash children with soap and water, especially their rear end, before they enter the pool.*
- *For diapered children, use swimming diapers or plastic pants to help contain stool and change diapers frequently. Parents should be aware that swimming diapers have limited effectiveness with liquid stool.*
- *Use diaper-changing facilities in the bathroom, not the poolside.*
- *Take young toilet-trained children for frequent bathroom breaks.*
- *Wash hands with soap and warm water after going to the toilet or changing diapers.*
- *Report fecal incidents or vomiting to pool staff as soon as possible.*
- *Follow pool staff instructions if a fecal incident or vomiting does occur and leave the pool immediately.*

Swim club members should be encouraged to take an active interest in the pool, report observations of unusual circumstances (e.g., cloudy water or fecal incidents), and work with club management to identify workable solutions to pool safety problems. CDC recommends that bathers be proactive and even check the pool water themselves for adequate chlorine (1–2 ppm) and pH (7.2–7.8) levels.

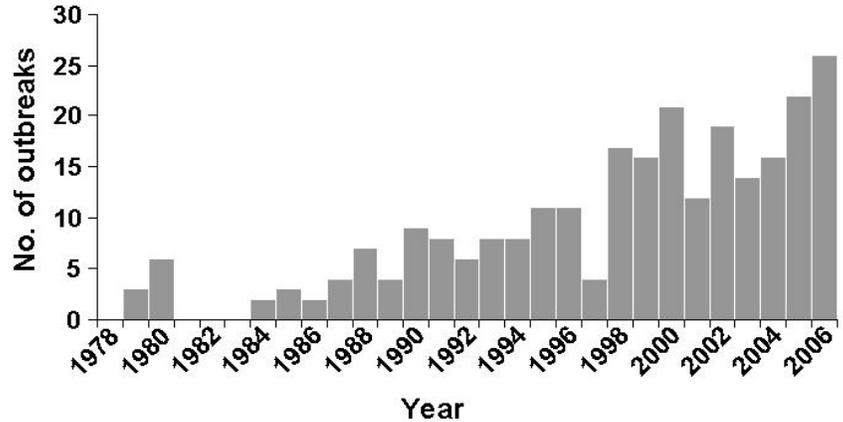
For more guidance on swimmer protection, visit

<http://www.cdc.gov/healthywater/swimming/audience-general-public.html>.

EPILOGUE

The number of recreational water-associated outbreaks in the United States has increased substantially since 1978 when CDC first began collecting reports.³ The increase has been caused by outbreaks of gastroenteritis (Figure 3) and likely results from a combination of factors, including the emergence of chlorine-resistant pathogens (e.g., *Cryptosporidium*), increased participation in aquatic activities by the public, and an increased number and variety of aquatic venues.

Figure 3. Number of recreational water-associated outbreaks of gastroenteritis by year—United States, 1978–2006.



Source: CDC Waterborne Disease and Outbreak Surveillance System

During 2005–2006, a total of 78 recreational water-associated outbreaks were reported in the United States, resulting in 4,412 cases of illness. Fifty-eight (74%) of the outbreaks occurred at treated water venues, resulting in 94% of the cases of illness.

As experienced in Vermont, problems contributing to outbreaks associated with treated recreational water in 2005–2006 include low disinfectant levels, inadequate water-quality monitoring, breakdowns of equipment and lengthy detection times, inadequately trained aquatic staff, and unclear chains of communication for resolving problems. Unfortunately, these problems are not limited to facilities associated with waterborne outbreaks. In a study of pool inspections at six sites across the United States, over half of all pools had at least one violation. Water-chemistry violations comprised 38.7% of total violations, followed by violations of the filtration and recirculation system (38.6%), and policy and management violations (22.7%). Approximately 8% of pools were closed immediately because of public health concerns.⁴

Prevention of outbreaks in treated recreational water venues is likely to be accomplished only through concerted efforts by pool operators, the public, and public health professionals.

- Pool operators should employ multiple mechanisms to prevent contamination of pools and transmission of pathogenic agents, including effective facility design and pool maintenance. Operators should implement diarrhea-exclusion policies and disinfection guidelines after fecal incidents. In addition, staff should be trained to perform pool operations, enforce policies, and educate young bathers and their parents about healthy swimming practices.
- The public should follow basic guidelines for healthy swimming. They should avoid swallowing water and stay out of the pool when they have diarrhea. Because fecal shedding of pathogens is common, bathers should use appropriate hygienic measures around pools (e.g., showering before swimming, taking children on frequent bathroom breaks, and changing diapers in the bathroom instead of at the poolside). Pool policies and design should support these efforts by the public. Increased public awareness of pool safety issues and action can promote better maintenance of pools by operators.

- Public health professionals should lead prevention efforts that include surveillance, health education, epidemiologic and laboratory studies, and environmental health research. Public health professionals should (1) require and improve training for pool inspectors, (2) update pool codes to stay current with changing pool designs and needs, and (3) lead efforts to educate aquatic staff and the public. They should also work with industry representatives in developing easier, more effective methods for treating pool water. In addition, because the majority of gastrointestinal illnesses can be spread by water, food, person-to-person contact, and animal-to-person contact, investigators should keep an open mind when investigating such cases and consider all possible sources of transmission during the investigation of an outbreak.

Improved pool operator and public education combined with more effective methods of water treatment should increase swimming safety and reduce the risk for waterborne diseases associated with recreational water facilities.

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APPENDIX A: Norovirus Questions and Answers

Available at <http://www.cdc.gov/ncidod/dvrd/revb/gastro/norovirus-qa.htm>

What are noroviruses?

Noroviruses are a group of viruses that cause the “stomach flu,” or gastroenteritis (GAS-tro-en-ter-I-tis), in people. The term norovirus was recently approved as the official name for this group of viruses. Several other names have been used for noroviruses, including:

- Norwalk-like viruses (NLVs)
- caliciviruses (because they belong to the virus family Caliciviridae)
- small round structured viruses.

Viruses are very different from bacteria and parasites, some of which can cause illnesses similar to norovirus infection. Like all viral infections, noroviruses are not affected by treatment with antibiotics, and cannot grow outside of a person’s body.

What are the symptoms of illness caused by noroviruses?

The symptoms of norovirus illness usually include nausea, vomiting, diarrhea, and some stomach cramping. Sometimes people additionally have a low-grade fever, chills, headache, muscle aches, and a general sense of tiredness. The illness often begins suddenly, and the infected person may feel very sick. In most people the illness is self-limiting with symptoms lasting for about 1 or 2 days. In general, children experience more vomiting than adults.

What is the name of the illness caused by noroviruses?

Illness caused by norovirus infection has several names, including:

- stomach flu – thi “stomach flu” is not related to the flu (or influenza), which is a respiratory illness caused by influenza virus.
- viral gastroenteritis – the most common name for illness caused by norovirus. Gastroenteritis refers to an inflammation of the stomach and intestines.
- acute gastroenteritis
- non-bacterial gastroenteritis
- food poisoning (although there are other causes of food poisoning)
- calicivirus infection

How serious is norovirus disease?

People may feel very sick and vomit many times a day, but most people get better within 1 or 2 days, and they have no long-term health effects related to their illness. However, sometimes people are unable to drink enough liquids to replace the liquids they lost because of vomiting and diarrhea. These persons can become dehydrated (lose too much water from their body) and may need special medical attention. . During norovirus infection, this problem with dehydration is usually only seen among the very young, the elderly, and people with other illness. (For more information see Is there a treatment for norovirus infection?)

How do people become infected with noroviruses?

Noroviruses are found in the stool or vomit of infected people. People can become infected with the virus in several ways, including:

- eating food or drinking liquids that are contaminated with norovirus;
- touching surfaces or objects contaminated with norovirus, and then placing their hand in their mouth;
- having direct contact with another person who is infected and showing symptoms (for example, when caring for someone with illness, or sharing foods or eating utensils with someone who is ill).

Persons working in day-care centers or nursing homes should pay special attention to children or residents who have norovirus illness. This virus is very contagious and can spread rapidly throughout such environments.

When do symptoms appear?

Symptoms of norovirus illness usually begin about 24 to 48 hours after ingestion of the virus, but they can appear as early as 12 hours after exposure.

Are noroviruses contagious?

Noroviruses are very contagious and can spread easily from person to person. Both stool and vomit are infectious. Particular care should be taken with young children in diapers who may have diarrhea.

How long are people contagious?

People infected with norovirus are contagious from the moment they begin feeling ill to at least 3 days after recovery. Some people may be contagious for as long as 2 weeks after recovery. Therefore, it is particularly important for people to use good handwashing and other hygienic practices after they have recently recovered from norovirus illness.

Who gets norovirus infection?

Anyone can become infected with these viruses. There are many different strains of norovirus, which makes it difficult for a person's body to develop long-lasting immunity. Therefore, norovirus illness can recur throughout a person's lifetime. In addition, because of differences in genetic factors, some people are more likely to become infected and develop more severe illness than others.

Is there a treatment for norovirus infection?

There is no vaccine to prevent norovirus infection. And there is no drug to treat people who are infected with the virus. Antibiotic drugs will not help if you have norovirus infection. This is because they fight against bacteria not viruses.

Norovirus illness is usually brief in people who are otherwise healthy. But, the infection can cause severe vomiting and diarrhea. This can lead to dehydration (loss of too much water from the body). During norovirus infection, young children, the elderly, and people with other illnesses are most at risk for dehydration. Symptoms of dehydration in adults and children include a decrease in urination, a dry mouth and throat, and feeling dizzy when standing up. A dehydrated child may also cry with few or no tears and be unusually sleepy or fussy.

Dehydration can lead to other serious problems. And severe dehydration may require hospitalization for treatment with intravenous (IV) fluids. Thus it is important to prevent dehydration during norovirus illness. The best way to protect against dehydration is to drink plenty of liquids. The most helpful fluids for this purpose are oral rehydration fluids (ORF)*. Other drinks that do not contain caffeine or alcohol can also help with mild dehydration. However, these drinks may not replace important nutrients and minerals lost due to vomiting and diarrhea.

Severe dehydration can be serious. If you think you or someone you are caring for is severely dehydrated, contact your healthcare provider.

*Several products with ingredients similar to those in ORFs can be used to prevent or treat mild dehydration. These products—called oral rehydration solutions—are sold as pre-mixed fluids. Following is a list of some oral rehydration solutions commonly available in U.S. food and drug stores: Infalyte, Kao Lectrolyte, Naturalyte, Oralyte, and Pedialyte. If you are unsure about which product to use or how to use these pre-mixed fluids, contact your healthcare provider.

Can norovirus infections be prevented?

You can decrease your chance of coming in contact with noroviruses by following these preventive steps:

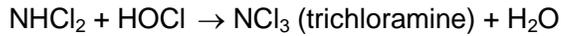
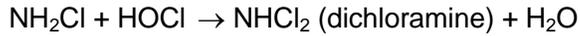
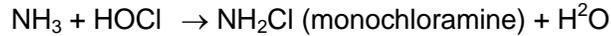
- Frequently wash your hands, especially after toilet visits and changing diapers and before eating or preparing food.
- Carefully wash fruits and vegetables, and steam oysters before eating them.
- Thoroughly clean and disinfect contaminated surfaces immediately after an episode of illness by using a bleach-based household cleaner.
- Immediately remove and wash clothing or linens that may be contaminated with virus after an episode of illness (use hot water and soap).
- Flush or discard any vomitus and/or stool in the toilet and make sure that the surrounding area is kept clean.

Persons who are infected with norovirus should not prepare food while they have symptoms and for 3 days after they recover from their illness (see food handler information sheet). Food that may have been contaminated by an ill person should be disposed of properly.

*This page last modified on February 23, 2010
Content on this page last reviewed on February 23, 2010*

APPENDIX B: Breakpoint Chlorination

Chloramines result from the reaction of ammonia compounds (formed from nitrogenous wastes in swimming pool water) with chlorine:



When trichloramine reacts with chlorine, it breaks down into nitrogen gas (which off-gasses), HCl, and water.

To remove the chloramines from a swimming pool, enough chlorine must be added to convert monochloramine, dichloramine, and trichloramine present in the water into nitrogen gas. Any chlorine added after all chloramines have been removed will be free chlorine, as long as no new contamination is introduced into the pool.

The process of adding chlorine until all chloramines are removed is called breakpoint chlorination. Breakpoint chlorination requires that sufficient chlorine be added to reach a concentration that is 10 times greater than the concentration of combined chlorine already in the pool.

Chlorine for breakpoint chlorination is usually added in the form of calcium hypochlorite (granules) or sodium hypochlorite (liquid). To determine how much of each of these formulations needs to be added to reach the desired chlorine concentration, you must consider the size of the pool and the amount of chlorine available in the formulation you are using. The following formulas can be used:

$$\text{Pounds of calcium hypochlorite} = \frac{\text{Pool volume (in gallons)} \times 8.3 \times \text{combined chlorine} \times 10 \times 1.5}{1,000,000}$$

$$\text{Gallons of sodium hypochlorite} = \frac{\text{Pool volume (in gallons)} \times 8.3 \times \text{combined chlorine} \times 10 \times 1.0}{1,000,000}$$

Example:

If the combined chlorine is 1.0 ppm, how much calcium hypochlorite should be added to the small activity pool at the swim club to remove the chloramines?

If the combined chlorine in the pool is 1.0 ppm and the pool volume is 13,900 gallons, using the above formula:

$$\begin{aligned} \text{Pounds of calcium Hypochlorite} &= \frac{\text{Pool volume (in gallons)} \times 8.3 \times \text{combined chlorine} \times 1.5 \times 10}{1,000,000} \\ &= \frac{13,900 \times 8.3 \times 1.0 \times 1.5 \times 10}{1,000,000} \\ &= 1.7 \text{ lbs.} \end{aligned}$$

This formula works fine, but can we reason this through?

- Because the combined chlorine in the swimming pool is 1.0 ppm, enough chlorine should be added to reach 10 ppm.
- Parts per million (ppm) is a weight-to-weight ratio of chlorine to water. Therefore, 10 ppm is
$$\frac{10 \text{ lbs. chlorine}}{1,000,000 \text{ lbs. water}}$$
- Water weighs 8.3 lbs./gallon. Therefore, the water in the activity pool (13,900 gallons) weighs 115,370 lbs.
- To achieve 10 ppm of chlorine in 115,370 lbs. of water, you will need
$$\frac{10 \text{ lbs. chlorine}}{1,000,000 \text{ lbs. water}} \times 115,370 \text{ lbs. water} = 1.15 \text{ lbs. chlorine}$$
- Calcium hypochlorite is 65% available chlorine (i.e., for every pound of calcium hypochlorite, you will get 0.65 lbs. chlorine). Therefore, to get 1.15 lbs. of chlorine, you need to have approximately
$$\frac{1 \text{ lb. calcium hypochlorite}}{0.65 \text{ lbs. chlorine}} \times 1.15 \text{ lbs. chlorine} = 1.7 \text{ lbs. calcium hypochlorite}$$

Note: The pool must be closed during breakpoint chlorination. It should only be done to an indoor pool if the pool is closed to swimmers and the pool area is well-ventilated to move irritants to the outside.

APPENDIX C: Excerpt from Original Questionnaire for Vermont Cohort Study – Exposures

SWIMMING EXPOSURES

5. Between Friday, January 30th and Monday, February 2nd, did you (your child) go into the swimming pool area at the swim club? This doesn't necessarily mean going swimming but whether you spent time in the pool area.

YES NO Refused Don't know
If NO, go to Question 8...

6. During the time you were in the swimming pool area, did you (your child) swim, wade in, or enter a swimming pool?

YES NO Refused Don't know
If NO, go to Question 8...

7. Did you (your child) actually swim in the pool? (note: doggy paddling = swimming)

YES NO Refused Don't know

8. Did you (your child) get your (his/her) face wet by either being splashed in the face or putting your (his/her) face or head in the water?

YES NO Refused Don't know

9. Did you (your child) get any water in your (his/her) mouth?

YES NO Refused Don't know
If NO, go to Question 7...

10. If yes, did you (he/she) swallow any of this water?

YES NO Refused Don't know

11. Did you (he/she) use the swimming pool slide?

YES NO Refused Don't know

FOOD AND OTHER EXPOSURES

12. Did you (your child) eat any food while in the pool area, including the kitchen/party room during this visit to the swimming club?

YES NO Refused Don't know
If NO, go to Question 11...

13. If you (he/she) ate and entered the pool, did you (he/she) eat before or after spending time in the pool.

BEFORE
AFTER
BEFORE AND AFTER
Refused
Don't know

14. If after, did you (he/she) shower or wash your (his/her) hands with soap between being in the pool and eating?

YES NO Refused Don't know

15. Did you (he/she) consume any drinks during your (his/her) visit to the pool?

YES NO Refused Don't know
If NO, go to Question 14...

16. If you (he/she) had a drink and entered the pool, did you (he/she) have this drink before or after spending time in the pool?

BEFORE
AFTER
BEFORE AND AFTER
Refused
Don't know

17. If after, did you (he/she) shower or wash your (his/her) hands with soap between being in the pool and having the drink?

YES NO Refused Don't know

18. Did you (he/she) use the locker room at the swimming club?

YES NO Refused Don't know
If NO, go to Question 16...

19. If yes, which pool locker room did you (he/she) use?

MEN'S
WOMEN'S
BOTH
Refused
Don't know

20. Did you (he/she) use the single rest room located in the pool area at the swimming club?

YES NO Refused Don't know

21. Did you (he/she) shower before or after going in the pool?

BEFORE
AFTER
BEFORE AND AFTER
Refused
Don't know

22. If yes, which shower did you (he/she) use?

MEN'S LOCKER ROOM SHOWER
WOMEN'S LOCKER ROOM SHOWER
SINGLE SHOWER OFF POOL
Refused
Don't Know

23. Did you (he/she) witness anyone vomiting during this visit to the swimming club?

YES NO Refused Don't know

24. Did you (he/she) witness any fecal accidents during this visit to the swimming club?

YES NO Refused Don't know

APPENDIX D: Calculating Relative Risk

A **relative risk** is the standard measure of association for a cohort study. It tells us how much more likely (or less likely) it is for persons exposed to a factor to experience illness, compared with persons not exposed to the factor.

The relative risk is the **ratio of the attack rates** of a disease among persons exposed to the factor and those not exposed to that factor. The **attack rate** is the incidence of disease among a group (i.e., the number of persons in the group who became ill divided by the total number of persons in the group).

$$\text{attack rate} = \frac{\text{No. ill persons in group}}{\text{No. of persons in group}}$$

$$\text{relative risk} = \frac{\text{attack rate for exposed persons}}{\text{attack rate for unexposed persons}}$$

A relative risk of

- **1.0 (or close to 1.0)** means the risk for illness is similar among the exposed and unexposed group, and exposure is not associated with illness,
- **Greater than 1.0** means the risk for illness is greater among the exposed than the unexposed group, and the exposure might be a risk factor for the illness, and
- **Less than 1.0** means the risk for illness is less among the exposed group than the unexposed group, and the exposure might be a protective factor.

In the Vermont cohort study, 39 of the 80 persons who attended events at the activity pool who swallowed water became ill. Nine of the 46 persons who attended events at the activity pool who did not swallow water became ill. Inserting these numbers into the 2-by-2 table results in the following:

Swallowed water	Ill	Well	TOTAL
Yes	39	41	80
No	9	37	46
TOTAL	48	78	126

$$\text{attack rate (swallowed water)} = \frac{\text{No. of persons who swallowed water who became ill}}{\text{No. of persons who swallowed water}}$$

$$= \frac{39}{80} = 49\%$$

$$\text{attack rate (did not swallow water)} = \frac{\text{No. of persons who did not swallow water who became ill}}{\text{No. of persons who did not swallow water}}$$

$$= \frac{9}{46} = 20\%$$

$$\text{relative risk (swallowed water)} = \frac{\text{attack rate for persons who swallowed water}}{\text{attack rate for persons who did not swallow water}}$$

$$= \frac{49\%}{20\%} = 2.5$$

Interpretation: Persons who swallowed water at the activity pool were 2.5 times more likely to experience illness than persons who did not swallow water.

APPENDIX E: Fecal Incident Response Recommendations for Pool Staff

Available at <http://www.cdc.gov/healthywater/pdf/swimming/pools/fecal-incident-response-recommendations.pdf>

For both formed stools and diarrheal fecal incidents

1. Close the pool to swimmers. If you have multiple pools that use the same filtration system — all pools will have to be closed to swimmers. Do not allow anyone to enter the pool(s) until the disinfection process is completed
2. Remove as much of the fecal material as possible (for example, using a net or bucket) and dispose of it in a sanitary manner. Clean and disinfect the item used to remove the fecal material (for example, after cleaning, leave the net or bucket immersed in the pool during disinfection). Vacuuming stool from the pool is not recommended.

For formed stools

3. Raise the chlorine to 2 parts per million (ppm), if less than 2 ppm, and ensure pH 7.5 or less and a temperature of 77°F (25°C) or higher. This chlorine concentration was selected to keep the pool closure time to approximately 30 minutes. Other concentrations or closure times can be used as long as the contact time (CT)* inactivation value* is free chlorine and pH should remain at these levels for at least achieved.
4. Maintain free chlorine concentration at 2 ppm and pH 7.5 or less for at least 25 minutes before reopening the pool. State or local regulators may require higher free chlorine levels in the presence of chlorine stabilizers, which are known to slow disinfection. Ensure that the filtration system is operating while the pool reaches and maintains the proper free chlorine concentration during the disinfection process.

*CT inactivation value refers to concentration (C) of free chlorine in ppm (or mg/L) multiplied by time (T) in minutes at a specific pH and temperature.

For diarrheal fecal incidents

3. If necessary, before attempting the hyperchlorination of any pool, consult an aquatics professional to determine the feasibility, the most optimal and practical methods, and needed safety considerations.
4. Raise the free chlorine concentration to 20 ppm and maintain pH 7.5 or less and a temperature at 77°F (25°C) or higher. The free chlorine and pH should remain at these levels for at least 12.75 hours to achieve the CT inactivation value of 15,300. *Cryptosporidium* CT values are based on killing 99.9% of *Cryptosporidium*. This level of *Cryptosporidium* inactivation cannot be reached in the presence of 50 ppm chlorine stabilizer, even after 24 hours at 40 ppm free chlorine, pH 6.5, and a temperature of 77°F (25°C). Extrapolation of these data suggest it would take approximately 30 hours to kill 99.9% of *Cryptosporidium* in the presence of 50 ppm or less cyanuric acid, 40 ppm free chlorine, pH 6.5, and a temperature of 77°F (25°C) or higher.
5. Confirm that the filtration system is operating while the water reaches, and is maintained, at the proper chlorine level for disinfection.
6. Backwash the filter after reaching the CT inactivation value. Be sure the effluent is discharged directly to waste and in accordance with state or local regulations. Do not return the backwash through the filter. Where appropriate, replace the filter media.
7. Allow swimmers back into the water only after the required CT inactivation value has been achieved and the free chlorine and pH levels have been returned to the normal operating range allowed by the state or local regulatory authority.

For both formed stools and diarrheal fecal incidents

Establish a fecal incident log. Document each fecal incident by recording date and time of the event, whether it involved formed stool or diarrhea, and the free chlorine and pH levels at the time of observation of the event. Before reopening the pool, record the free chlorine and pH levels, the procedures followed in response to the fecal incident (including the process used to increase chlorine levels if necessary), and the contact time.

Revised March 16, 2010