

Typhoid in Tajikistan

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 Tajikistan in 1997.^{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 vary by country, state, and outbreak.

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

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

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

Teaching materials required: None.

Time required: 3–3.5 hours.

Language: English.

Level of case study: Basic ___ Intermediate X Advanced ___

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INSTRUCTOR'S VERSION
Typhoid Fever in Tajikistan

Learning Objectives:

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

1. list health problems common in countries with economic hardships, deteriorating infrastructure, and displaced populations;
2. discuss the steps typically used to develop hypotheses on the source of an infectious disease outbreak;
3. interpret the results of a matched case-control study;
4. list activities that should be included in the evaluation of a public water system associated with an outbreak;
5. define surface water and groundwater;
6. list the steps in collecting water samples from a point-of-use water tap;
7. describe point-of-use water disinfection and give examples of proven approaches; and
8. describe the clinical features, epidemiology, and control of typhoid fever.

PART I. OUTBREAK DETECTION

Tajikistan is one of five Central Asian countries that were formerly part of the Soviet Union (Figure 1). Tajikistan is one of the poorest of these countries, with less than 7% of its land available for cultivation.

Figure 1. Location of Tajikistan including the country's capital and largest city, Dushanbe.



Tajikistan became an independent nation in 1991 as the result of the dissolution of the former Soviet Union. The shift in its status from being a member of a totalitarian republic to an independent nation brought with it certain challenges. Basic public services (e.g., health care, water supply, and sewer systems), previously guaranteed for even the poorest nations in the Soviet Union, were no longer supported through the Soviet cost-sharing system. Financial hardships and inadequate tariffs in Tajikistan severely limited provision of services and maintenance of equipment. Faulty design and installation of equipment while Tajikistan was still part of the Soviet Union added to these problems.

To make matters worse, shortly after becoming an independent nation, Tajikistan experienced a civil war that continued until a cease-fire occurred in 1996. During the civil war, an estimated 50,000 lives were lost and 1.2 million persons were internally displaced.³ In addition, a substantial number of trained technical and professional workers left the country.

By 1997, the country's economy and much of its infrastructure had collapsed. Consequently, the health of the people of Tajikistan suffered. Diseases rarely seen before the dissolution of the Soviet Union reappeared in increasing numbers.

Question 1: What health problems are common in countries with displaced populations, economic hardships, and deteriorating infrastructure?

Common health problems in these settings include

- *vaccine preventable diseases (e.g., measles and diphtheria);*
- *waterborne diseases;*
- *foodborne diseases;*
- *other infectious diseases (e.g., malaria and sexually transmitted diseases);*
- *malnutrition;*
- *pregnancy-related health problems resulting from inadequate prenatal care (e.g., low birth weight and increased infant and maternal mortality rates);*
- *injuries, violence, and sexual assaults; and*
- *mental health problems (e.g., depression and alcohol and drug abuse).*

Julie Stachowiak summarizes the health effects of the dissolution of the Soviet Union in the article "Russia and the Former Soviet Union" published in "The Body: The Complete HIV/AIDS Resource" in 1998, as follows:

"The collapse of the Soviet Union brought further damage to an already inadequate public health system. As a result, many infectious diseases, including diphtheria, cholera, and hepatitis B, reached epidemic proportions. Rates of sexually transmitted diseases skyrocketed in several of the former republics, with statistics indicating an increase of between 200 and 500 percent in syphilis and chlamydia. Price deregulation created a dramatic inflation in food prices, sparking widespread malnutrition. Prostitution increased as the local currency continued to decrease in value and foreign business people began arriving. Civil unrest in the countries of Central Asia and the Transcaucasian region, as well as unbearable economic conditions, has led to mass migration to large cities in Russia and Ukraine. High suicide rates, widespread alcoholism, and a shortened life span are further indications of the turmoil faced by the countries of the former Soviet Union."

The complete article is available at <http://www.thebody.com/content/art14037.html>.

Residents of Tajikistan received primary health care at designated polyclinics on the basis of their place of residence. The polyclinics provided ambulatory care and certain acute care services but lacked surgical and post-operative care facilities. Limited hospital beds at nationally run hospitals were available for patients needing in-patient services. Cases of notifiable disease were reported each week from the polyclinics and hospitals to the Sanitary Epidemiologic Service (SES), the public health unit that monitored infectious diseases.

In February 1997, an increase in typhoid fever cases was reported in Dushanbe, the capital of Tajikistan (population approximately 600,000). Although typhoid fever was endemic in this area, more than 2,000 cases had been reported during January 29–February 11 (i.e., a 2-week period), compared with approximately 75 cases each week during the previous month. During the same 2-week period in 1996, only 23 cases had been reported.

All typhoid fever patients were hospitalized at one of six full-service hospitals in the city, as required by a central government edict. SES staff studied the situation to determine the likelihood of an outbreak.

Question 2: Besides an outbreak, what are other possible explanations for the increase in cases of typhoid fever reported to the SES? How would you go about ruling out these other explanations?

Even if the reported number of cases of a disease exceeds the expected number, the excess might not be caused by an outbreak. Other reasons for an increase in case counts should be considered. Investigators like to divide potential explanations for an increase in case counts into two categories: an artificial increase in cases or a real increase in cases.

In an artificial increase in cases, the perceived increase does not reflect an actual change in the occurrence of the disease but rather is the result of changes in the detection or reporting of cases. Reasons for artificial increases in case counts include

- *increased testing of patient specimens,*
- *initiation of new testing or testing techniques by the laboratory,*
- *laboratory error in identification,*
- *contamination of patient specimens,*
- *changes in reporting procedures,*
- *increased interest in reporting, or*
- *errors in data entry.*

In a real increase, the occurrence of disease increases. Reasons for real increases in case counts include

- *an increase in population size,*
- *changes in population characteristics,*
- *an increase in incidence because of random variation in incidence (i.e., chance), or*
- *a true outbreak.*

As a first step in exploring the increase in typhoid fever cases in Tajikistan, SES investigators confirmed the diagnosis of typhoid fever in a sample of patients admitted to one of the Dushanbe hospitals. They also examined laboratory testing procedures and reagents at all six hospitals. No evidence of laboratory error or contamination of cultures was identified.

SES investigators were unable to identify recent events that might have led to an increase in the completeness of case reporting. Notifiable disease reporting procedures had not changed since the early 1980s.

SES investigators noted that the civil war had resulted in the displacement of substantial numbers of Tajikistan citizens and an increase in the Dushanbe population. However, movement of the displaced persons was spread over a lengthy period and seemed an unlikely explanation for the sudden increase in typhoid fever cases during January–February of 1997.

SES staff concluded that the increase in typhoid fever cases was real and likely represented an outbreak. Because previous typhoid fever outbreaks had been associated with foods and beverages sold by street vendors, the city government prohibited such sales. However, considerable debate remained about the source of the outbreak and appropriate control measures.

Question 3: How might you approach the development of hypotheses on the source of the typhoid fever outbreak?

To identify exposures of greatest interest in studying a disease or health problem, investigators

- 1. review known information about the causative agent and consider likely risk factors or exposures for the disease on the basis of the epidemiology of the agent and previous outbreak investigations, keeping in mind that new risk factors and vehicles are possible;*
- 2. examine the descriptive epidemiology of cases of the disease to characterize persons at risk and to identify commonalities among cases; and*
- 3. undertake hypothesis-generating interviews to explore exposures and to further identify commonalities among cases.*

On the basis of this information, investigators can gain clues and generate hypotheses about exposures or risk factors for the disease specific to the situation under investigation. They can then test these hypotheses through more rigorous epidemiologic, laboratory, and/or environmental health studies.

PART II. HYPOTHESIS GENERATION

SES investigators pursued different lines of investigation to gain clues about the typhoid fever outbreak in Dushanbe. The first step was to review known information about the disease and risk factors on the basis of its epidemiology and previous outbreaks.

Question 4: How is typhoid fever transmitted? What is the incubation period? (For additional information, see Appendix A.)

Salmonella enterica serovar Typhi, the causative agent of typhoid fever, lives only in humans and is spread by the fecal-oral route (i.e., it is excreted in the feces of one host and finds its way to the mouth of the next host in some way). No other animal vectors are known. Approximately 3% of persons infected with *Salmonella* Typhi, called carriers, recover from typhoid fever but continue to carry the bacteria and can shed it in their feces for months.

Typhoid fever is spread by eating food contaminated by the feces of an infected person, drinking contaminated liquid, or by direct contact with an infected person.

The incubation period for typhoid fever depends on the number of *Salmonella* Typhi bacteria ingested. (The larger the number of bacteria initially ingested, the more rapid the onset of symptoms.) The incubation period ranges from 3 days to over 60 days. The usual range is 8-14 days.

SES staff then reviewed the typhoid fever cases reported through the notifiable disease surveillance system and characterized the cases by person, place, and time (i.e., performed the descriptive epidemiology).

Question 5: For this analysis, what case definition would you use for typhoid fever? Would you use a sensitive case definition or a specific case definition?

A sensitive case definition is one that will capture a substantial proportion of true cases. Criteria for a sensitive case definition tend to be less stringent and include only symptoms and signs of the disease as opposed to laboratory confirmation. The disadvantage of a sensitive case definition is that it will also capture a substantial number of false-positives (i.e., persons who meet the case definition but do not have the disease of interest).

A specific case definition is one that will be more likely to exclude false-positives; therefore, patients meeting a specific case definition are likely to have the disease of interest. A specific case definition tends to be more stringent and includes laboratory confirmation or specific testing (e.g., subtyping results). The disadvantage of a specific definition is that it can exclude a substantial proportion of true cases, resulting in an increased number of false-negatives (i.e., persons with the disease who do not meet the case definition).

(Note: Sometimes the terms confirmed, probable, and possible are used to describe case definitions that are more or less specific in nature. A definition for a confirmed case usually includes laboratory confirmation of the disease. A definition for a probable case [also referred to as a presumptive case] includes typical clinical features of the disease or clinical features unique to the disease without laboratory confirmation and sometimes an epidemiologic linkage to a confirmed case. A definition for a possible case [also referred to as a suspect case] has fewer of the typical clinical features of the disease or features of the disease that are not particularly unique to the disease.)

Early in an outbreak investigation, when investigators are trying to determine the magnitude of an outbreak and characterize persons at risk for the infection, a sensitive case definition typically is used.

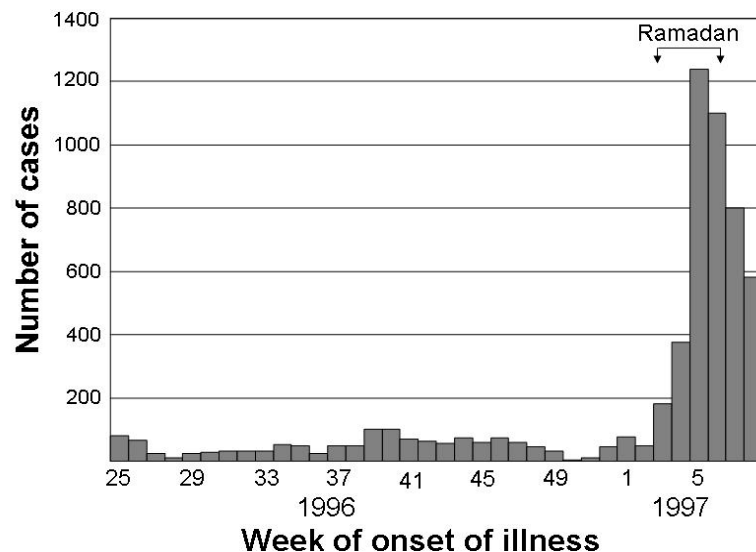
For typhoid fever, a sensitive case definition might include a combination of clinical signs and symptoms typical of typhoid fever (e.g., a sustained fever, headache, malaise, anorexia, constipation or diarrhea, nonproductive cough, or rash). Inclusion of an epidemiologic link to a laboratory-confirmed case will increase the probability that the person has typhoid fever. Because knowledge regarding an outbreak is limited early in an investigation, restrictions on time, place, and person are not advisable.

To characterize the typhoid fever cases associated with the Dushanbe outbreak, SES investigators defined a case of typhoid fever as a physician diagnosis of typhoid fever or isolation of *Salmonella* Typhi from the stool, blood, or urine of a Dushanbe resident (i.e., a relatively sensitive case definition). Investigators analyzed typhoid fever cases reported to SES with onset of illness since January 1.

A total of 3,822 patients meeting the typhoid fever case definition had onset of illness since January 1. Of these cases, 127 had onset of illness from January 1–14 (median of 64 cases each week) and 3,695 had onset of illness from January 15 to February 18 (median of 724 cases each week) (Figure 2).

Among the cases reported during January 15–February 18, the following signs and symptoms were reported: sustained fever (91% of cases), headache (81%), weakness (76%), chills (73%), loss of appetite (67%), abdominal pain (51%), vomiting (39%), diarrhea (30%), and rose-colored spots (6%). Blood, stool, or urine cultures confirmed 1,145 (31%) of the cases.

Figure 2. Cases of typhoid fever by week of onset of illness, Dushanbe, Tajikistan, June 1996–February.



Source: Dushanbe SES Notifiable Disease Surveillance System

The median age of patients was 16 years (range: <1–80 years); 51% were male. Cases were spread across the city with varying rates of infection by polyclinic catchment area (Figure 3).

Forty-eight (1.3%) of the 3,695 patients had died. Mortality rates were lowest among patients aged <10 years (0.3%) and highest among those aged >39 years (1.4%).

Question 6: Interpret the descriptive epidemiology of the typhoid fever cases. Are signs and symptoms among patients consistent with typhoid fever? Are patients clustered by selected demographic characteristics? What is the course of the epidemic and does it appear to be over?

Signs and symptoms reported among patients are consistent with typhoid fever but not unique to this disease. Without laboratory confirmation, case counts can include persons with other diseases.

Cases were distributed somewhat equally among males and females and affected all age groups. Patients resided throughout the city; however, certain polyclinic catchment areas had higher attack rates than others.

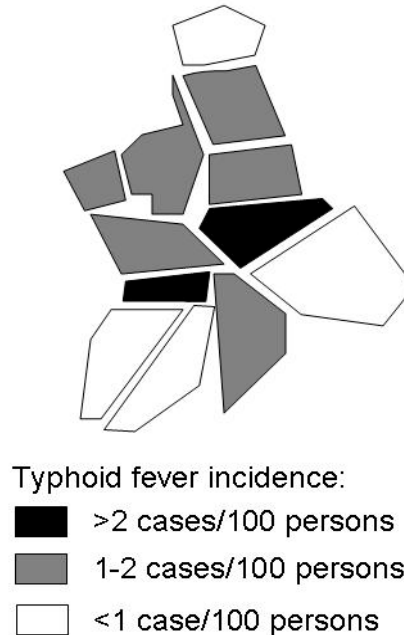
Starting the third week of January, the number of typhoid fever cases began to increase. Cases peaked during the first week of February, followed by a more gradual decrease. Onset of illness among a substantial number of patients occurred during Ramadan, a month-long Muslim observance involving a fast from food and water from sunrise to sunset that began on January 10, 1977. Given the variation in incubation periods for typhoid fever, it is difficult to say if there is an association between the outbreak and Ramadan.

If the majority of typhoid fever cases have been reported, the pattern of onset among patients might indicate a point-source outbreak with a limited duration of exposure and that the outbreak is on a downward trend. However, a substantial number of cases might not be reported yet.

Detailed hypothesis-generating interviews were conducted to detect common and suspicious exposures among a sample of the typhoid fever patients. Interviews were undertaken with 10 patients who had culture-confirmed illness. These patients lived in the catchment areas of five different polyclinics and ranged in age from 5 to 69 years. Six of the patients were female. All of the patients had had onset of symptoms during the first 2 weeks of February.

Hypothesis-generating interviews revealed that all of the patients had purchased groceries from state-approved markets. However, four of the patients had also purchased food from local street vendors, with fruits and vegetables being the most commonly purchased items. No market, street vendor, restaurant, or social event was identified in common among the patients.

Figure 3. Incidence rate of typhoid fever by registered polyclinic, Dushanbe, Tajikistan, January 15–February 18, 1997.



Source: Dushanbe SES Notifiable Disease Surveillance System

The households of all patients included in hypothesis-generating interviews were supplied with public water. All but one patient reported that the water was often cloudy and occasionally had a foul smell.

Only one patient had traveled outside the city during the previous 6 weeks; seven patients had had visitors who normally resided outside Dushanbe staying in their home because of Ramadan (i.e., a month-long Muslim observance involving a fast from food and water from sunrise to sunset that began on January 10). None of the patients knew each other. Two patients knew someone else who had been similarly ill.

Question 7: Using information available to you at this point, state your leading hypotheses on the mode of transmission, the source of the outbreak, and the period of interest.

Mode of transmission: A geographically widespread illness affecting both sexes and all age groups accompanied by complaints about water quality in the affected community is indicative of a disease spread by drinking water.

Source: All patients included in the hypothesis-generating interviews had used the Dushanbe public water supply.

Period of interest: Given the incubation period for typhoid fever (range: 3–60 days, average: 8–14 days), the period of interest is the month or so before the peak of the epidemic. Although cases counts appear to be on a downward trend, the decline in cases during recent weeks might reflect lags in reporting. Investigators should probably assume it is ongoing.

SES investigators suspected the public water supply as the source of the Dushanbe typhoid fever outbreak. The widespread occurrence of cases throughout the city, affecting both sexes and all age groups, was indicative of a waterborne outbreak. Complaints during the hypothesis-generating interviews about the quality of the public water further heightened their suspicions.

Investigators initiated both epidemiologic and environmental health studies to confirm their hypothesis.

PART III. AN EPIDEMIOLOGIC STUDY TO TEST THE HYPOTHESIS

SES investigators conducted a case-control study to test the hypothesis that the public water system was the source of the typhoid fever outbreak in Dushanbe.

Beginning March 24, patients hospitalized with typhoid fever in Dushanbe were recruited to participate in the case-control study. For the study, a case was defined as an illness in a person that included the following:

Clinical criteria

- sustained fever (i.e., oral temperature $\geq 101.5^{\circ}\text{F}$ [38.5°C] for ≥ 7 days), and
- one or more other signs and symptoms indicative of typhoid fever (e.g., weakness, stomach pains, headache, loss of appetite, or rose-colored rash), and
- culture of stool or blood positive for *Salmonella* Typhi.

Restrictions on time, place, and person

- onset of symptoms after February 1,
- resident of Dushanbe, and
- person with earliest onset of symptoms in household.

Question 8: Why did investigators use a different case definition for the case-control study than for performing the descriptive epidemiology? If cases were culture-confirmed, why did investigators include symptoms of infection in the case definition? Why did investigators include only the first case in a household in the study?

To test the hypothesis on the source of an outbreak, investigators include cases that are very likely to be true cases because misclassification of noncases as cases can produce erroneous results. Use of a more specific case definition (e.g., one that includes laboratory confirmation of infection with Salmonella Typhi) will help exclude false-positives.

A limited number of persons infected with S. Typhi recover from typhoid fever but continue to carry the bacteria and shed them in their feces for months. To focus on cases of typhoid fever that are associated with the current outbreak, investigators should exclude carriers who were infected before this outbreak. Inclusion of signs and symptoms in the case definition will help identify more recent cases.

Typhoid fever can be spread from person to person. An outbreak initially transmitted by food or water can then be spread from person to person (i.e., secondary transmission). Persons infected through secondary spread will not have the same risk factors for infection as those infected through the original source of the outbreak and should be excluded from the study. Persons in households of case-patients have an increased risk for infection through secondary spread. Excluding all but the first case in a household helps exclude persons infected through secondary spread.

Case-patients were interviewed within 5 days of hospital admission by a trained SES interviewer, using a standardized questionnaire. Questions focused on exposures during the 30 days before onset of illness.

Within 5 days of interviewing each case-patient, investigators selected neighborhood control subjects from households in which no one had experienced fever for ≥ 3 consecutive days during the previous 90 days. Control subjects were recruited by going systematically from door-to-door, starting at the case-patient's house; control subjects were then matched with case-patients by age group. Two to three control subjects were identified for each case-patient.

Control subjects were interviewed by using the same standardized questionnaire as case-patients, except that exposure information was requested for the 30 days before the interview.

During March 24–April 7, a total of 45 case-patients and 123 healthy control subjects were enrolled in the case-control study. SES investigators tabulated the results and set a P value of 0.05 as the cut-off for statistical significance.

On the basis of these analyses, case-patients were similar to control subjects with respect to age, sex, and nationality (Table 1). Exposure to potential risk factors for infection with *S. Typhi*, however, differed between case-patients and control subjects (Table 2).

Tables 1. Characteristics of case-patients and control subjects, case-control study, Dushanbe, Tajikistan, 1997.

Characteristic	Case-patients (n=45)	Control subjects (n=123)
Median age (yrs)	13	14
Age range (yrs)	3–41	5–49
Male (%)	62	60
Nationality (%)		
Tajiks	80	83
Uzbek	15	11
Russian	1	1
Other	4	5

Table 2. Exposures to selected risk factors for infection with *Salmonella Typhi*, case-control study, Dushanbe, Tajikistan, 1997.

Exposure*	Case-patients exposed/total cases† (%)	Control subjects exposed/total control† (%)	Matched odds ratio	95% confidence interval	P value
Drinking water that had not been boiled	19/39 (49)	12/117 (10)	6.5	3–24	<0.001
Using water obtained from an outside tap	10/42 (24)	10/116 (9)	9.1	1.6–82	0.006
Eating food obtained from a street vendor	23/42 (55)	35/117 (30)	2.9	1.4–7.2	0.004
Boiling water in the home	30/42 (71)	108/113 (96)	0.2	0.05–0.5	<0.001
Eating apples	34/43 (79)	109/117 (93)	0.3	0.08–0.9	0.03
Eating butter	8/43 (19)	60/116 (52)	0.2	0.06–0.5	<0.001
Eating onions	21/43 (49)	81/117 (69)	0.5	0.2–1.0	0.04

*Exposure during the 30 days before becoming ill (case-patients) and during the 30 days before the interview (control subjects)

†Denominator does not always total to 45 (case-patients) or 123 (control subjects) because certain subjects could not remember if they had had the exposure.

Question 9: Interpret the matched odds ratios for exposures in the case-control study.

The odds ratio is the measure of association for a case-control study. It tells us how much higher the odds of exposure are among case-patients compared with control subjects. An odds ratio of

- *1.0 (or approximately 1.0) means that the odds of exposure among case-patients is the same as the odds of exposure among control subjects; the exposure is not associated with the disease;*
- *greater than 1.0 means that the odds of exposure among case-patients is greater than the odds of exposure among control subjects; the exposure might be a risk factor for the disease; and*
- *less than 1.0 means that the odds of exposure among case-patients is lower than the odds of exposure among control subjects; the exposure might be protective against the disease.*

The odds of drinking water that had not been boiled was 6.5 times higher among case-patients than control subjects; the odds of using water obtained from an outside tap, 9 times higher; the odds of eating food from a street vendor, approximately 3 times higher. These findings were statistically significant; therefore, these exposures might be risk factors for infection.

The odds of boiling water in the home and eating butter were 0.2 times lower among case-patients than control subjects; the odds of eating apples, 0.3 times lower; and the odds of eating onions, 0.5 times lower. These findings were statistically significant; therefore, these exposures might be protective against infection.

On the basis of the matched case-control study, infection with *S. Typhi* in Dushanbe was associated with drinking water that had not been boiled during the 30 days before onset of symptoms. The odds ratio increased with the amount of water consumed each day (Figure 4). Drinking at least 1 glass of water that had not been boiled had a matched odds ratio of 3; drinking 2 glasses had a matched odds ratio of 12; and drinking > 2 glasses had a matched odds ratio of 40.

Obtaining water from a tap outside the home and eating food obtained from street vendors were also associated with illness. Using boiled water in the home and eating butter, apples, or onions were determined to be protective factors.

Factors not associated with illness (data not shown) included type of toilet facilities; drinking beverages with ice; eating or drinking at restaurants or a friend's or relative's home; traveling outside Dushanbe or receiving visitors who usually reside outside Dushanbe; and consuming raw fruits and vegetables (other than apples and onions), dairy products (other than butter), and medicines.

Investigators undertook a multivariate logistic regression analysis that included all exposures identified as significantly associated with infection in the univariate analysis (Table 3).

Figure 4. Odds ratios by amount of water consumed per day that had not been boiled, case-control study, Dushanbe, Tajikistan, 1997.

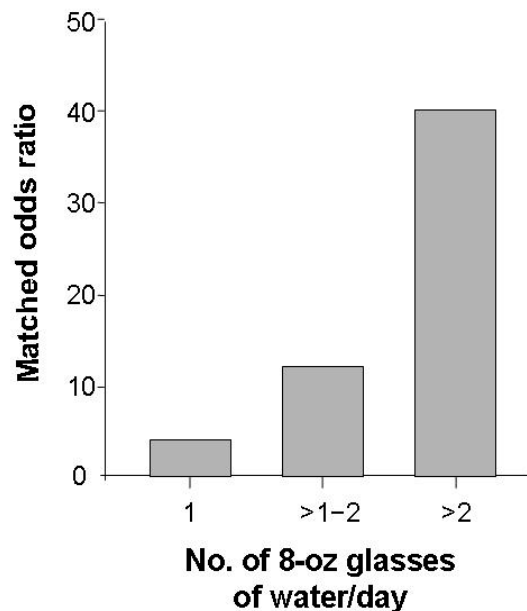


Table 3. Multivariate analysis of reported exposures to risk factors for infection with *Salmonella* Typhi, case-control study, Dushanbe, Tajikistan, 1997.

Exposure*	Matched odds ratio	95% confidence interval	P value
Using water obtained from an outside tap	16.7	2.0–138	0.009
Drinking water that had not been boiled	9.6	2.7–34	0.0005
Eating food obtained from a street vendor	1.5	0.9–5.6	0.3
Eating onions	0.6	0.5–2.1	0.2
Eating apples	0.2	0.04–0.9	0.03
Eating butter	0.1	0.04–0.4	0.001
Boiling water in home	†	†	†

*Exposure during the 30 days before becoming ill (case-patients) and during the 30 days before the interview (control subjects)

†Although significantly associated with typhoid fever in the univariate analysis, this variable was not included in multivariate logistic regression analyses because of its inverse correlation with drinking water that had not been boiled.

Question 10: Can you postulate why eating apples and butter were protective against typhoid fever? (Does an apple a day really keep the doctor [typhoid fever] away?)

No plausible biological reason exists for butter and apples to be protective against typhoid fever. Eating these foods probably represented another factor not directly measured in the case-control study (e.g., persons who could afford to buy these foods might have had better living conditions or more consistent access to safe water or eating apples and butter might help satiate a person and cause them to drink less water).

PART IV. ENVIRONMENTAL STUDIES AND WATER SUPPLY INVESTIGATION

Concurrent with the case-control study, SES investigators evaluated the Dushanbe public water supply to identify factors that might have allowed introduction of pathogenic organisms into the drinking water or the survival of such organisms.

Question 11: What activities would you include in the evaluation of the public water supply? With whom would you talk? What records or data sources would you review?

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

Activities

Because every water treatment plant differs, the activities included in the evaluation of any particular plant will also vary (and can vary depending on plant conditions at the time of the outbreak). The following activities are commonly included in the evaluation of water treatment plants:

Determine the quality of raw water by

- *collecting information on the source of the water for the plant and means in place to protect the source from contamination;*
- *viewing maps of the watershed and touring the area;*
- *collecting information on conditions likely to affect water quality at the source (e.g., construction, flooding, spring run-off, wastewater treatment plant outflows, or presence of animals); and*
- *inspecting the wellhead (groundwater) or intake point (surface water).*

Describe the water treatment process by

- *reviewing blueprints and diagrams of the plant;*
- *touring the plant;*
- *collecting detailed information on procedures used to treat water, including chemicals added and dosages, techniques for adding and mixing chemicals, order of addition of chemicals, settling time, contact time, and type of filtration;*
- *observing procedures used to treat water;*
- *collecting information about recent changes in water treatment procedures;*
- *inspecting equipment used in water treatment (e.g., chlorine feeding equipment, sedimentation tanks, and filters) and collecting information on maintenance or breakdown of equipment;*
- *collecting information on plant hydraulics and determining water flow rates and patterns; and*
- *inspecting equipment used to monitor flow rates or chemical treatment processes.*

Determine the effectiveness of the water treatment process by

- *collecting untreated (raw) and treated water specimens for testing for total coliforms, fecal indicators (e.g., *Escherichia coli*), turbidity, and possibly the causative agent;*
- *ascertaining routine testing procedures used to determine water quality including frequency, timing, and how recorded and quality-control testing;*
- *reviewing routine test results for period of interest (e.g., residual disinfectant, pH, and turbidity);*
- *measuring temperature and pH of raw water;*
- *measuring disinfectant residual of treated water;*
- *calculating contact time (i.e., period between introduction of disinfectant and water use); and*
- *collecting historical samples of treated water (e.g., water bottles, toilet tanks in houses where residents have been away, storage tanks, taps at seldom-used and dead-end locations).*

Determine the integrity of the water distribution system by

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

Persons who should be consulted

- *water treatment plant superintendent and operators;*
- *maintenance technicians;*
- *laboratorians who oversee water-quality tests;*
- *engineers who designed water treatment plant;*
- *engineers or state agency employees who approved water treatment plant design;*
- *consulting engineers knowledgeable about water treatment facilities, water system hydraulics, or other specialty areas; and*
- *governmental regulator who oversees the water utility's compliance with drinking water regulations.*

Records and data sources of interest

- *results of routine water-quality tests (e.g., total coliform counts, fecal indicators [if any], turbidity, and total and residual chlorine) of both untreated and treated water and monitoring triggers;*
- *records of water treatment procedures (e.g., logs of chemicals used and dosages);*
- *logs of system maintenance and repairs at the plant or to the water distribution system;*
- *water customer complaint log;*
- *records of damage or repairs in and around water distribution system (e.g., water main breaks, sewer system maintenance, and road repairs); and*
- *weather reports that might reflect conditions for increased contamination of surface water supplies (e.g., flooding, low temperatures, and spring run-off).*

To evaluate the Dushanbe public water supply, SES investigators first talked with the superintendent of public water and viewed maps of the watersheds for the water treatment plants. They then toured all of the water treatment plants (and associated wells) and spoke with water treatment plant operators and maintenance technicians. Investigators observed procedures used to treat the water at each plant and inspected equipment used in water treatment.

SES investigators learned that the city of Dushanbe had four water treatment plants that used surface and groundwater. The two treatment plants in the northern part of the city (i.e., the Napornaya and Samotechnaya Stations) used surface water from the Varzob River. The two treatment plants in the southern part of the city (i.e., the Kafernigan and South-West Stations) used groundwater.

Question 12: What is meant by the terms surface water and groundwater? How do the health hazards differ for the two?

Groundwater is water derived from aquifers (i.e., natural reservoirs below the earth's surface). Groundwater results from precipitation or surface water that percolates downward through the soil or between the crevices and fractures in rock. The percolation of groundwater through the soil can remove certain contaminants, particularly microorganisms, and is usually free of such organisms as Giardia and Cryptosporidium. Groundwater, however, tends to be harder than surface water, because it contains minerals from the rocks. Chemical contaminants (e.g., pesticides or nitrates) can persist in groundwater supplies.

Surface water is water from sources open to the atmosphere (e.g., rivers, lakes, and reservoirs). Surface water is more vulnerable to contamination from different sources (e.g., industrial waste, animal and human waste, pesticides, fertilizers, and erosion), and if not treated correctly, can present a greater health hazard to users than groundwater.

Because of varying health hazards, different degrees of treatment are used for surface water than for groundwater sources.

The Varzob River's source is in the Hissar Mountain range, 72 km north of Dushanbe, and is fed by the Siyoma, Ojuk, Kondara, Maikhura and Tagob Rivers. Heavy rains in the winter and spring and snowmelt result in periodic flash floods along the watershed. Lack of wastewater purification facilities or storage in villages and factories along the river resulted in the discharge of communal wastes directly into the river. Within the Dushanbe city limits, water was drawn from the Varzob River through a system of canals into the surface water treatment plants (i.e., Napornaya and Samotechnaya Stations).

Typically, the water was strained and held in open sedimentation basins where particulates were allowed to settle out naturally. Chlorine was added directly to the sedimentation basins before the water was passed through sand filters to allow for adequate contact time. From the filters, water was pumped into the distribution system without further storage.

The water for the two groundwater treatment plants (i.e., Kafernigan and South-West Stations) was pumped directly from the wells into holding tanks and from the holding tanks into the public water distribution system without treatment.

Question 13A: What are the usual steps in treating a public water supply to make it safe to drink?

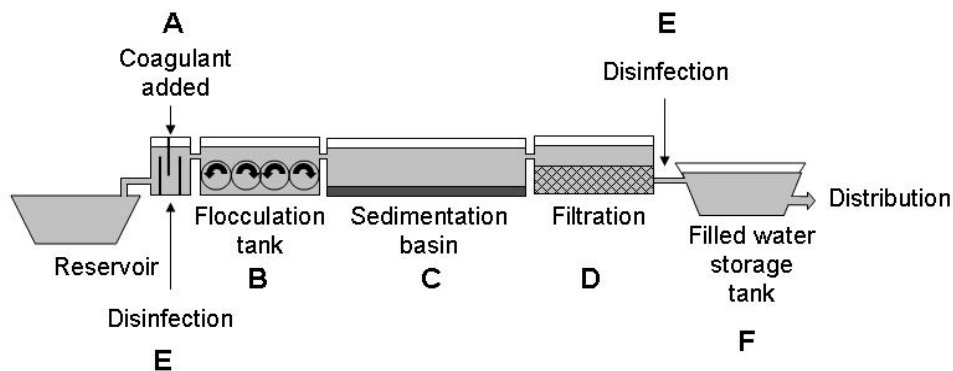
The amount and type of treatment applied by a public water system varies with the source type and quality of the raw water. The most commonly used steps in treating public water include flocculation and sedimentation, filtration, and disinfection.

- *Flocculation (B in Figure A) refers to the water treatment process that coagulates small particles suspended in the water into larger particles (called floc), which then settle out of the water as sediment. Alum and iron salts or synthetic organic polymers are used to promote coagulation (A in Figure A). Settling or sedimentation (C in Figure A) occurs naturally as flocculated particles settle out of the water. Coagulation and flocculation are effective in removing fine suspended particles that attract and hold bacteria, viruses, and parasites to their surface. They also remove certain organic matter present in water.*

- *Filtration (D in Figure A) removes finer particles from the water (e.g., clays and silts, natural organic matter, precipitates from other treatment processes, iron and manganese, and microorganisms) and enhances the effectiveness of disinfection. (Note: Filters do not remove such contaminants as gasoline, oil, pharmaceuticals, and biotoxins.) Filtration is based on multiple simultaneous actions, including mechanical straining between the particles of the filter (i.e., the pores), adsorption of particles to filter materials caused by different physical forces (e.g., van der Waals and coulombs forces), and biochemical processes in the biologic layer of a filter (i.e., a thin film of active microorganisms sometimes called the “Schmutzdecke”). Filters can be made of different materials, but sand is the most common for industrial filtration.*
- *Disinfection (E in Figure A) is used to ensure that potentially dangerous microbes not removed by sedimentation or filtration are killed. Chlorine is a commonly used, effective disinfectant. It has a residual effect in the pipes that distribute water to homes and businesses (i.e., can provide limited protection against contaminants introduced in the distribution system) and can be measured throughout the distribution system. Ozone and ultraviolet (UV) radiation are effective disinfectants, but neither are effective in controlling contaminants in the distribution pipes (i.e., they leave no residual in the system). To allow for sufficient contact time (i.e., time required to kill certain microorganisms with a particular disinfectant), chemical disinfectants can be added early in the water treatment process and again before release of water into the distribution system for adequate residual disinfection.*

Following the final addition of chemical disinfectants, water is placed in a closed tank or reservoir (F in Figure A) for disinfection to occur (i.e., contact time). The water then flows through pipes to homes and businesses in the community.

Figure A. Typical steps in public water treatment (INSTRUCTOR VERSION ONLY)



Source: Adapted from Australian Cooperative Research Centre (CRC) for Water Quality and Treatment. *Drinking water facts. Drinking water treatment.* Adelaide, South Australia: CRC; 2008.

Question 13B: Would you make any changes to the routine water treatment processes at the surface water treatment stations in Dushanbe? At the groundwater treatment stations?

Surface water treatment would benefit from the following changes:

- *addition of a coagulant before sand filtration (with subsequent agitation) to promote aggregation of suspended particles into larger particles that are more likely to settle out (Note: This lengthens the life of the filters and decreases the chlorine needed to disinfect the water.);*
- *addition of chlorine after sedimentation and filtration because chlorine added before these processes is likely to be used up through binding to organic material and other compounds;*

- storage of chlorinated water before distribution to allow for adequate disinfectant contact time;
- monitoring the turbidity or cloudiness of treated water; and
- monitoring the chlorine concentration in water leaving the plant and at the taps of consumers to determine if the chlorine residual is adequate to ameliorate contamination within the distribution system. (The World Health Organization [WHO] sets a free chlorine residual of ≥ 0.5 mg/L [after ≥ 30 minutes contact time at $\text{pH} < 8.0$] as a sufficient residual to maintain the quality of water through the distribution network.)

Ground water treatment can benefit from the following:

- addition of chlorine before distribution into the system to act on microorganisms that might find their way into the treated water in the distribution system and
- monitoring the chlorine concentration in water leaving the plant and at the taps of consumers to determine if the chlorine residual is adequate to ameliorate contamination within the distribution system. (WHO sets a free chlorine residual of ≥ 0.5 mg/liter [after ≥ 30 minutes contact time at $\text{pH} < 8.0$] as a sufficient residual to maintain the quality of water through the distribution network.)

On inspection of the surface water treatment stations, investigators noted that the sedimentation basins were filled with silt and algae. Dredging machines used to remove the silt were broken. Sand filters had formed mud balls (i.e., conglomerations of filter material that form if a filter is not cleaned adequately) and displayed substantial fouling with iron-oxide that can compromise the filtration process.

Water at the surface water treatment stations had not been chlorinated regularly since December. The chlorine-producing facility in Yavan, Tajikistan, which once supplied chlorine to the entire country, had closed in 1996.

Inspections of the groundwater treatment stations were unrevealing. The wells were in good condition and wellhead seals were functioning correctly. However, approximately half of the pumps at these stations were not operational, limiting the ability to provide the city with adequate water pressure. Plant workers had scavenged spare parts to maintain the functionality of the remaining pumps.

SES investigators tested treated water samples from each of the water treatment plants for turbidity and fecal coliforms.

Question 14: What is turbidity? What do fecal coliforms indicate?

Turbidity is a measure of the clarity of the water and is caused by impurities (e.g., clay, silt, finely divided inorganic and organic matter, and microscopic organisms). Turbidity in raw water increases the chlorine demand and the amount of chlorine that must be added to achieve the desired residual chlorine level. Turbidity in treated water can provide food for pathogens and shelter against disinfectants. The particles have been demonstrated to actually adsorb pathogens and, if not removed, can promote regrowth of pathogens in the distribution system.



Turbidity is expressed in terms of nephelometric turbidity units (NTUs). A higher number of NTUs indicates more turbidity. In the majority of developed countries, turbidity of water from public water treatment plants must be <1.0 NTU.

Fecal coliforms are bacteria located in the feces of humans, other mammals, and birds and are, therefore, indicators of fecal contamination of water (and the potential presence of pathogenic organisms). Fecal coliforms are reported as numbers of colonies/100 mL of water. In the majority of developed countries, no fecal indicators (e.g., fecal coliforms or E. coli) are allowed in water from public water treatment plants.

The turbidity of treated water from the Napornaya Station was 150 nephelometric turbidity units (NTUs). Fecal coliforms were 132 colony forming units (CFU)/100 mL. Treated water from the Samotechnaya Station had a turbidity of 70 NTUs; fecal coliforms were 118 CFU/100 mL. Both groundwater plants pumped fecal-coliform-free water with a turbidity of 0 NTUs.

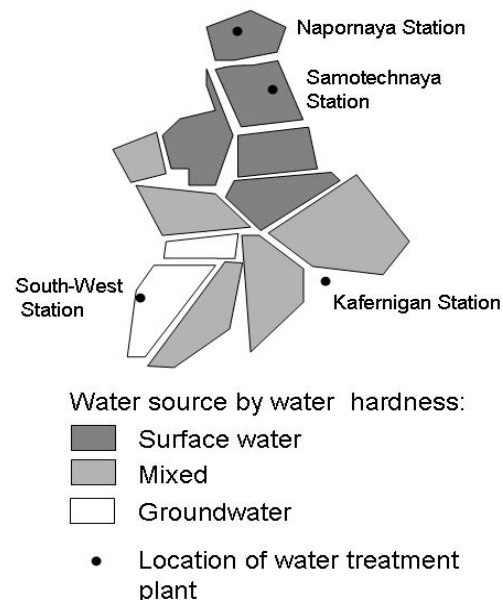
Water leaving all four water treatment plants entered an interconnected distribution system where surface and groundwater blended. To distinguish the source of water supplied to different parts of the city, SES investigators measured water hardness at the treatment plants and at a sample of consumer taps. They determined that the northern part of the city received water primarily from the surface water treatment plants. The southern part of the city received water primarily from the groundwater treatment plants. The central part of the city received water from both the surface and the ground water treatment plants (Figure 5).

Question 15: Reexamine the incidence of typhoid fever by polyclinic as illustrated in Figure 3 in light of the water-quality data and water distribution maps from the four Dushanbe water treatment plants (Figure 5). Does this information provide further clues about problems within the public water supply?

The incidence of typhoid fever was not closely correlated with the likely drinking water source (i.e., surface water versus ground water).

Although water leaving the groundwater treatment plant was free of fecal coliforms, areas supplied primarily by these plants still had cases of typhoid fever. In fact, one of the polyclinic areas with the highest rates of typhoid fever received groundwater predominantly. This and subsequent testing of water from consumers' taps indicates that contamination was not limited to the surface water source, but was occurring in the distribution system as well. Investigators should seek reasons for cross-contamination within the distribution system (e.g., breaks in pipes or low or intermittent changes in water pressure).

Figure 5. Water source by polyclinic, Dushanbe, Tajikistan, 1997.



The water distribution system in Dushanbe was approximately 690 km in total length and consisted mainly of steel and cast-iron pipelines. Approximately 5% of pipes were asbestos or plastic. Distribution pipes had corroded over the years, and breaks occurred intermittently throughout the city.

SES investigators undertook a community survey to assess domestic water quality and use in Dushanbe. Households were selected from each polyclinic catchment area by using a stratified random-sampling scheme. At each house or apartment, investigators recorded the number of residents, frequency of water outages and other problems, and attitudes toward water use. They also collected water from the tap for fecal coliform testing and quantified water usage.

Question 16: How would you collect a water sample from a water tap for fecal coliform testing?

The International Association of Milk, Food, and Environmental Sanitarians, Inc. (IAMFES) recommends the following steps in collecting a water sample from a water tap:

Before drawing a sample from a water tap, ensure the tap is connected to the supply to be evaluated. Do not collect samples through garden hoses, sprayers, or swivel faucets. Uncouple these connections or choose different taps. Do not flame outlets because this does not improve the sample quality.

Collect the sample in a container that has been cleaned, rinsed, and sterilized. If residual chlorine might be present in the water, use containers that contain a small amount of 2% sodium thiosulfate, which combines with the free chlorine and prevents the lethal effects of chlorine on any microorganisms present. Keep sample containers closed until the moment they are to be filled.

To take a sample from the service line (i.e., the pipe that leads from the public distribution line to the user's plumbing), allow the water to run to waste for 5–10 seconds. Adjust the flow so that the thiosulfate is not washed out of the container. Carefully remove the cap or stopper and hold the container near its base. Fill the container without rinsing and replace the cap or stopper as quickly as possible. Leave an air gap (e.g., 1 inch from the top of the container) to facilitate mixing of the sample at the laboratory.

To take a distribution line sample, open the tap fully and let the water run to waste for enough time to empty the service line (or if in doubt, for 5 minutes) and proceed as previously described.

The sample should be stored in the dark at temperatures between 2–4°C (35.6–39.2°F). Ideally, bacteriologic samples should be examined within 6–24 hours of collection.

SES investigators learned that low and intermittent water pressure was common across the city, resulting in water outages on a daily basis. Apartment buildings often had supplemental water pumps that were activated at times of low water pressure. Residents in households and apartment buildings without supplemental water pumps were forced to obtain water from outside taps. In addition, nonstandard connections to waterlines were commonly used to supply homes. Investigators also observed that water pipes ran inside storm drains along roadsides.

Water usage at the surveyed households was substantial. On average, 1,000 L of water were used/person/day, the majority of which was wasted. A total of 300 L/person/day were lost because of open taps within the households, and another 300 L/person/day were lost because of broken pipes or faucets within the house. An additional 400 L/person/day were wasted because of open or broken taps or pipes in public areas. (**Note:** For comparison, according to a 2006 United Nations Development Programme report,⁴ water usage was approximately 575 L/person/day in the United States and 200–300 L/person/day in Europe.)

Surveyed residents considered the water supply a free commodity. Approximately 2% of domestic users paid the tariff charged by the public water utility, which by the majority of standards was quite low (i.e., US\$0.004/1,000 L equivalent for domestic consumers). Residents did not consider running taps to be wasteful or as a contributing factor to the typhoid fever epidemic.

Based on the water samples collected during the survey, 97% of household and community taps throughout the city had water contaminated with fecal coliforms. The average fecal coliform concentration in water samples was 175 CFU/100 mL.

Question 17: Summarize the actions necessary to ensure safe drinking water in the city of Dushanbe. Which actions can be undertaken more quickly? Which will be longer-term efforts?

Many actions are necessary to ensure safe drinking water in the city of Dushanbe. Some actions can be undertaken more quickly, whereas others will take substantial financial resources and more time.

Shorter-term actions include

- *procuring adequate amounts of chlorine and coagulant;*
- *changing the water treatment processes at both the surface and groundwater treatment plants (see answer to Question 13B);*
- *monitoring chlorine residuals following water treatment and at consumers' taps; and*
- *thoroughly training water treatment plant staff.*

Longer-term actions include

- *protecting the watershed of the Varzob River, including improved sewage storage, treatment, and disposal;*
- *repairing or replacing equipment at the water treatment plants (e.g., dredging machinery, sand filters, and pumps);*
- *repairing and replacing the aging water distribution system; and*
- *educating the public regarding water conservation to decrease water wastage across the city (and the treatment load on the water treatment plants).*

PART V. PREVENTION AND CONTROL MEASURES

Prevention and control of typhoid fever and other waterborne diseases in Dushanbe required many actions, including improved protection of the watershed of the Varzob River, repair or replacement of equipment at the water treatment plants (e.g., dredging machinery, sand filters, and pumps), thorough training of water treatment plant staff, changes to the water treatment processes, procurement of adequate amounts of chlorine and coagulant, and repair and replacement of the aging water distribution system. In addition, public education on water conservation was needed to decrease water wastage across the city.

Officials estimated that these efforts might cost at least US\$150 million and require years to complete. Public health officials considered implementing point-of-use water treatment to protect the public's health while more costly improvements were being made to the water system.

Question 18: What is point-of-use water treatment? What are examples of point-of-use water treatment methods?

Point-of-use water treatment is treatment of water in the household of the individual consumer. In settings where resources or time are unavailable for infrastructure improvements to the public water supply, point-of-use treatments are an alternative in making water safe to drink.

Different point-of-use water treatment methods have been tried. Five interventions (i.e., boiling, chlorination, solar disinfection, ceramic filtration, and use of flocculant/disinfectant powder) have been demonstrated to reduce waterborne diseases in developing countries. A brief description of each follows.

Boiling is a standard practice in much of the developing world and is used widely to purify tap water on a short-term basis after natural disasters or interruptions in a water treatment or distribution system. Different organizations recommend different lengths of boiling time. To kill Cryptosporidium, a pathogen resistant to multiple forms of water treatment, CDC recommends boiling water at a rolling boil for 1 minute (at altitudes greater than 6,562 feet [$>2,000$ m], boil water for 3 minutes). Benefits of boiling include its effectiveness against different pathogens (e.g., viruses, spores, cysts, oocysts, and worm eggs) and a cultural awareness of the need to boil drinking water to make it safe. Drawbacks include the cost (e.g., for gathering and transporting fuel), the time needed to boil water, lack of residual protection that can prevent recontamination of the water, the change in taste (caused by the release of air from the water), the health impact from indoor air pollution, the potential for burn accidents, and the environmental impact from burning biomass fuel and deforestation.

Point-of-use chlorination usually involves adding a sodium hypochlorite solution to a standardized water container, agitating the mixture, and allowing it to stand for a set period (e.g., 30 minutes). Benefits of point-of-use chlorination are residual protection against subsequent contamination, user acceptability because of ease of use, scalability, and low cost. Drawbacks of point-of-use chlorination include user taste and odor objections, decreased efficacy against certain organisms (e.g., protozoal parasites), and decreased efficacy when using turbid water.

Ceramic filtration uses a mechanical process to remove contaminants from drinking water. The most widely distributed ceramic filter, Potters for Peace (additional information available at <http://www.pottersforpeace.org/>), has small (0.6–3.0 μm) pores and is impregnated with colloidal silver that acts as a disinfectant against bacteria. The Potters for Peace ceramic filter can filter 1–2 L each hour. Benefits of ceramic filtration include user acceptability because of ease of use, long life if the filter remains unbroken, and potential for local filter production. Drawbacks of ceramic filtration include unknown effectiveness against viruses, lack of residual protection that can prevent recontamination of the water, the need for user education to clean the filter and receptacle, and slow filtration rates.

Solar disinfection uses increased temperature, UV light, and oxidative chemistry to inactivate disease-causing organisms. Users place 0.3–2-L plastic soda bottles filled with low-turbidity water in the sun (on a roof or a rack) for 1–2 days, depending on the climate. Benefits of solar disinfection include acceptability to users because of the minimal cost, ease of use, and minimal change in water taste. Recontamination is unlikely with this method because water is consumed directly from the bottles in which it is treated. Drawbacks include the need to pretreat turbid water, the limited volume of water that can be treated at one time, the length of time required to treat water, and the supply of plastic bottles required.

Point-of-use flocculation and chlorination incorporates both a chemical coagulation step for particle removal and a chlorination step for disinfection, producing high-quality finished water. In a system developed by the Proctor and Gamble Company, users add a packet of flocculant and chlorine to 10 L of water, stir it, and let the mixture settle. The water is then strained through a cloth and held for 20 minutes to allow sufficient contact time with the disinfectant. Benefits of point-of-use flocculation and chlorination include high-quality water even with turbid source waters, residual protection against recontamination, and visual improvement in the water. Drawbacks are the complexity of the process (i.e., multiple steps for correct use), the need for specific equipment (e.g., two buckets, a cloth, and a stirrer), and the higher relative cost per liter of water treated.

Factors that should be considered in choosing a point-of-use treatment for a particular setting include

- the effectiveness at eliminating potential pathogens;
- protection against recontamination (i.e., residual protection);
- acceptability to users regarding time and effort necessary for the process and taste and odor of the treated water; and
- cost and availability of materials and parts.

The following table summarizes these factors for the point-of-use treatment methods.

Table A. Comparison of point-of-use treatment methods (INSTRUCTOR ONLY)

Treatment	Effective-ness against viruses	Effective-ness against bacteria	Effective-ness against protozoa	Residual protection	User concerns	Cost/L treated (US\$)
Boiling	High	High	High	No	Inconvenience; costs; taste; health effects; environmental impact	--
Chlorination	Medium	High	Low	Yes	Taste/odor of chlorine	0.0001–0.0005
Ceramic filtration	Unknown	Medium–High	High	No	Slow process	0.00034–0.0014
Solar disinfection	High	High	High	No	Slow process	No cost after initial procurement of bottles
Flocculation and chlorination	High	High	High	Yes	Taste/odor of chlorine, complexity of process, cost	0.01

Source: Lantagne DS, Quick R, and Mintz ED. Household water treatment and safe storage options in developing countries: a review of current implementation practices. Washington, DC: Woodrow Wilson International Center for Scholars; 2007.

CDC. Preventing diarrheal disease in developing countries: proven household water treatment options. USAID-sponsored activity. Atlanta, GA: US Department of Health and Human Services, CDC; 2008.

SES investigators worked with the Tajikistan Ministry of Health in developing a citywide public education campaign about point-of-use water treatment. A health educator from the Ministry of Health was designated to lead and coordinate campaign efforts.

Question 19: What are the likely goals of the public education campaign? What steps would you include in planning the campaign? Who might you recruit to help educate and motivate residents to use point-of-use such water treatments?

The goals of the public education campaign are to

- *make community members aware of the existing water safety problem, the link between contaminated water and disease, and the health benefits of water treatment;*
- *educate them on how to treat their water by using the selected treatment method;*
- *motivate them to treat the water correctly and consistently; and*
- *educate and encourage other health behaviors that will enhance the benefits of water treatment (e.g., safe water storage practices, good hand-washing practices, and adequate sanitation).*

The campaign should start with investigating the different options for point-of-use water treatment and identifying the most culturally appropriate option for the target population on the basis of effectiveness, acceptability to the community, and feasibility. Next, understanding the priorities and concerns of the target population and exploring their attitudes toward water quality and treatment practices are critical for ensuring success and motivating the community. Identification of the main forms of communication among the population (e.g., media or community meetings) and community members who can help educate and motivate community members will be beneficial at this point.

Changing the behavior of a community in a lasting way is slow and can be difficult. Therefore, strategies to train and motivate community members will be needed. Behavior change techniques include social marketing (i.e., the systematic application of marketing concepts and techniques to achieve desired behavioral goals for a social good [e.g., making persons associate product use with a better lifestyle and addressing myths associated with product use]), community mobilization (i.e., a process by which the community defines its own problems, decides which are highest priority, and organizes itself to address the priority problems), motivational interviewing (i.e., a small-scale interpersonal communication method that moves persons more quickly through the stages of behavioral change), and health education. Health education alone is insufficient to bring about behavior change, but it can be an important contributor by raising awareness of waterborne diseases and how to prevent them.

Assistance from the local community will improve the success of the campaign. Teachers and school administrators, religious leaders and leaders/members of other faith-based organizations, staff from the polyclinics, political leaders, and community/neighborhood activists are among those who might help motivate members of the target population to change their behavior and encourage healthy water practices.

EPILOGUE

Use of multiple barriers to keep water contaminants from entering the water supply and surviving is the best approach to achieving a healthy public water supply. Development of multiple barriers to protect the water means that the system will continue to perform adequately despite the failure of part of the system.

The Dushanbe typhoid fever outbreak resulted from failures at multiple points in the water treatment and distribution process. The factors contributing to the state of water services in Dushanbe included

- chronically contaminated surface waters caused by discharge of untreated sewage into the river and heavy flooding each spring;
- inadequate treatment processes (e.g., lack of chlorination because of inadequate supplies, improperly maintained sand filters, and lack of residual chlorine levels in water leaving the water treatment stations);
- disrepair of the water treatment plants resulting from inadequate initial design, unavailable or low-quality of materials and equipment, limited financial resources, and departure of trained staff;
- frequent low and intermittent water pressure because of nonoperational water pumps at treatment facilities, breakages in the water distribution lines, and water wastage in the community; and
- inadequate monitoring of the water system to identify and correct problems.

In 2002, the World Bank began funding the Dushanbe Water Supply Project. Loans were approved to address the most critical deficiencies of the water supply, including replacement of pumps and other equipment at the treatment plants and repair of major sections of the distribution system. Despite improvements, many Dushanbe residents still had inadequate water service and outbreaks of typhoid fever reoccurred on an annual basis. In 2006, the World Bank approved additional funds to continue work on the water system. Renovations and repairs are ongoing.⁵

Although the investigation of the typhoid fever outbreak in Dushanbe presents a dramatic third world image, similar problems occur elsewhere. In 2007, the U.S. Environmental Protection Agency estimated that 240,000 water mains in the United States break each year, resulting in a loss of 1.7 trillion gallons of water.⁶ These problems are attributed to factors that are reminiscent of the Dushanbe situation and include reductions in resources devoted to water treatment system maintenance, a growing backlog of needed repairs, aging treatment equipment and distribution pipes, and loss of trained personnel to maintain the systems.

In the majority of U.S. cities, water supplies have not yet been adversely affected. However, a growing number of localities have had serious problems resulting in at least a temporary loss of potable water and substantial commitment of resources to correct the problem. If steps are not taken to understand and address these growing problems, a widespread decline in drinking water quality and reliability, even in the United States, is possible.

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APPENDIX A: Typhoid and Paratyphoid Fever (by Eric Mintz)

Also available at <http://wwwnc.cdc.gov/travel/yellowbook/2010/chapter-2/typhoid-paratyphoid-fever.aspx>.

Infectious Agent

Typhoid fever is an acute, life-threatening febrile illness caused by the bacterium *Salmonella enterica* serotype Typhi. Paratyphoid fever is a similar illness caused by *S. Paratyphi* A, B, or C.

Mode of Transmission

- Humans are the only source. No animal or environmental reservoirs have been identified.
- Typhoid and paratyphoid fever are most often acquired through consumption of water or food that have been contaminated by feces of an acutely infected or convalescent individual or a chronic asymptomatic carrier.
- Transmission through sexual contact, especially among men who have sex with men, has rarely been documented.

Occurrence

- An estimated 22 million cases of typhoid fever and 200,000 related deaths occur worldwide each year; an additional 6 million cases of paratyphoid fever are estimated to occur annually.
- Approximately 400 cases of typhoid fever and 150 cases of paratyphoid fever are reported to CDC each year among persons with onset of illness in the United States, most of whom are recent travelers.

Risk for Travelers

- Risk is greatest for travelers to South Asia (6 to 30 times higher than all other destinations). Other areas of risk include East and Southeast Asia, Africa, the Caribbean, and Central and South America.
- Travelers to South Asia are at highest risk for infections that are nalidixic acid-resistant or multidrug-resistant (i.e., resistant to ampicillin, chloramphenicol, and trimethoprim–sulfamethoxazole).
- Travelers who are visiting friends or relatives are at increased risk.
- Although the risk of acquiring typhoid or paratyphoid fever increases with the duration of stay, travelers have acquired typhoid fever even during visits of less than 1 week to countries where the disease is endemic.

Clinical Presentation

- The incubation period of typhoid and paratyphoid infections is 6–30 days. The onset of illness is insidious, with gradually increasing fatigue and a fever that increases daily from low-grade to as high as 102° F–104° F (38.5° C–40° C) by the third to fourth day of illness. Headache, malaise, and anorexia are nearly universal. Hepatosplenomegaly can often be detected. A transient, macular rash of rose-colored spots can occasionally be seen on the trunk.
- Fever is commonly lowest in the morning, reaching a peak in late afternoon or evening. Untreated, the disease can last for a month. The serious complications of typhoid fever generally occur only after 2–3 weeks of illness, mainly intestinal hemorrhage or perforation, which can be life threatening.

Diagnosis

- Infection with typhoid or paratyphoid fever results in a very low-grade septicemia. Blood culture is usually positive in only half the cases. Stool culture is not usually positive during the acute phase of the disease. Bone-marrow culture increases the diagnostic yield to about 80% of cases.
- The Widal test is an old serologic assay for detecting IgM and IgG antibodies to the O and H antigens of *Salmonella*. The test is unreliable, but is widely used in developing countries because of its low cost. Newer serologic assays are somewhat more sensitive and specific than the Widal test, but are infrequently available.
- Because there is no definitive test for typhoid or paratyphoid fever, the diagnosis often has to be made clinically. The combination of a history of being at risk for infection and a gradual onset of fever that increases in severity over several days should raise suspicion of typhoid or paratyphoid fever.

Treatment

- Specific antimicrobial therapy shortens the clinical course of typhoid fever and reduces the risk for death.
- Empiric treatment of typhoid or paratyphoid fever in most parts of the world would utilize a fluoroquinolone, most often ciprofloxacin. However, resistance to fluoroquinolones is highest in the Indian subcontinent and increasing in other areas. Injectable third-generation cephalosporins are often the empiric drug of choice when the possibility of fluoroquinolone resistance is high.
- Patients treated with an appropriate antibiotic still require 3–5 days to defervesce completely, although the height of the fever decreases each day. Patients may actually feel worse during the time that the fever is starting to go away. If fever does not subside within 5 days, alternative antimicrobial agents or other foci of infection should be considered.

Preventive Measures for Travelers

Vaccine

- CDC recommends typhoid vaccine for travelers to areas where there is a recognized increased risk of exposure to *S. Typhi*.
- The typhoid vaccines currently available do not offer protection against *S. Paratyphi* infection.
- Travelers should be reminded that typhoid immunization is not 100% effective, and typhoid fever could still occur.
- Two typhoid vaccines are currently available in the United States.
 - Oral live, attenuated vaccine (Vivotif vaccine, manufactured from the Ty21a strain of *S. Typhi* by Crucell/Berna)
 - Vi capsular polysaccharide vaccine (ViCPS) (Typhim Vi, manufactured by sanofi pasteur) for intramuscular use
- Both vaccines protect 50%–80% of recipients.
- Table 2-10 provides information on vaccine dosage, administration, and revaccination. The time required for primary vaccination differs for the two vaccines, as do the lower age limits.
- Primary vaccination with oral Ty21a vaccine consists of four capsules, one taken every other day. The capsules should be kept refrigerated (not frozen), and all four doses must be taken to achieve maximum efficacy. Each capsule should be taken with cool liquid no warmer than 37° C (98.6° F), approximately 1 hour before a meal. This regimen should be completed 1 week before potential exposure. The vaccine manufacturer recommends that Ty21a not be administered to infants or children <6 years of age.

- Primary vaccination with ViCPS consists of one 0.5-mL (25-µg) dose administered intramuscularly. One dose of this vaccine should be given at least 2 weeks before expected exposure. The manufacturer does not recommend the vaccine for infants and children <2 years of age.

Vaccine Safety and Adverse Reactions

Information on adverse reactions is presented in Table 2-11. Information is not available on the safety of these vaccines in pregnancy; it is prudent on theoretical grounds to avoid vaccinating pregnant women. Live, attenuated Ty21a vaccine should not be given to immunocompromised travelers, including those infected with HIV. The intramuscular vaccine presents a theoretically safer alternative for this group. The only contraindication to vaccination with ViCPS vaccine is a history of severe local or systemic reactions after a previous dose. Neither of the available vaccines should be given to persons with an acute febrile illness.

Precautions and Contraindications

Theoretical concerns have been raised about the immunogenicity of live, attenuated Ty21a vaccine in persons concurrently receiving antimicrobials (including antimalarial chemoprophylaxis), IG, or viral vaccines. The growth of the live Ty21a strain is inhibited in vitro by various antibacterial agents. Vaccination with Ty21a should be delayed for >72 hours after the administration of any antibacterial agent. Available data do not suggest that simultaneous administration of oral polio or yellow fever vaccine decreases the immunogenicity of Ty21a. If typhoid vaccination is warranted, it should not be delayed because of administration of viral vaccines. Simultaneous administration of Ty21a and IG does not appear to pose a problem.

Table(s) 2-10a. Dosage and schedule for typhoid fever vaccination

Oral, live, attenuated Ty21a vaccine (Vivotif)

Vaccination	Age (Years)	Dose/Mode of Administration	No. of Doses	Dosing Interval	Boosting Interval
Primary series	≥6	1 capsule ¹ , oral	4	48 hrs	Not applicable
Booster	≥6	1 capsule ¹ , oral	4	48 hrs	Every 5 years

¹ Administer with cool liquid no warmer than 98.6°F (37°C).

Table(s) 2-10b. Dosage and schedule for typhoid fever vaccination

Vi Capsular polysaccharide vaccine (Typhim Vi)

Vaccination	Age (Years)	Dose/Mode of Administration	No. of Doses	Dosing Interval	Boosting Interval
Primary series	≥2	0.50 mL, intramuscular	1	Not applicable	Not applicable
Booster	≥2	0.50 mL, intramuscular	1	Not applicable	Every 2 years

¹ Administer with cool liquid no warmer than 98.6°F (37°C).

Table 2-11. Common adverse reactions to typhoid fever vaccines

Vaccine	Fever Reactions	Headache Reactions	Local Reactions
Ty21a1	0%–5%	0%–5%	Not applicable
Vi Capsular polysaccharide	0%–1%	16%–20%	7% erythema or induration 1 cm

¹ The side effects of Ty21a are rare and mainly consist of abdominal discomfort, nausea, vomiting, and rash or urticaria.