Engineers and Enteric Fever:
Designing Against Disease

by **Trudy E. Bell**

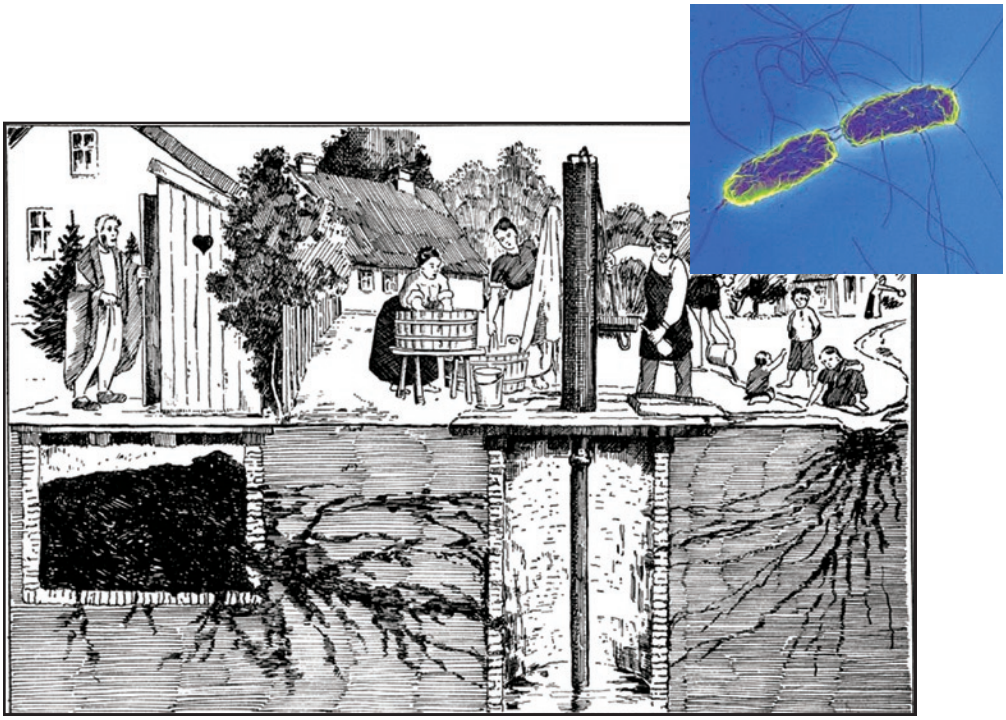


Figure 1. A drawing from 19th century Denmark illustrates the problem posed by waterborne typhoid bacteria. Above: The description of hydraulic engineer Hiram F. Mills of the *Salmonella typhi* bacillus is as accurate today as it was in 1917: "... this species is a rod with rounded ends, the diameter being about one thirty-thousandth of an inch and the length about one ten-thousandth of an inch. When very highly magnified, fine hair-like appendages (cilia) may be seen extending from near either end."[20] Bacillus image: Dr. Volker Brinkmann, Max Planck Institute for Infection Biology.

Hygienically speaking, before World War I, the United States was a third-world country. Private and municipal supplies drew untreated water drawn from wells, lakes, and rivers that literally also served as sewers. Not surprisingly, by 1900, leading causes of death included infectious waterborne diseases: cholera, dysentery, typhoid, and diarrhea.

Within three decades, however, the nation became a first-world country. Typhoid fever and other waterborne scourges were nearly eradicated—*before* the advent of antibiotics, widespread vaccinations, or other medical treatment. Recent statistical analysis reveals that life expectancy at birth had skyrocketed from 47 in 1900 to 63 in 1940, and that "clean water was responsible for nearly half the total mortality reduction in major cities."[1] Why such a sudden and dramatic improvement in U.S. water supplies?

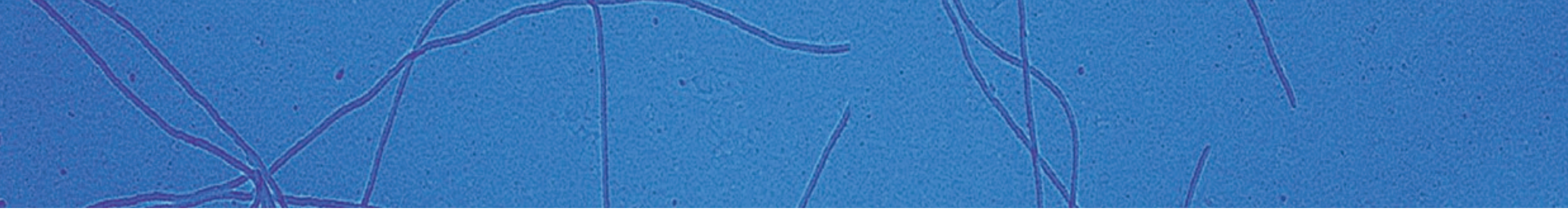
It started with a small band of interdisciplinary pioneers at the Massachusetts Institute of Technology who partnered with the Massachusetts State Board of Health to design against disease—and ended up transforming sanitary science and technology nationwide. Declared one of their leaders in 1922: "For the first time in the history of science, engineers, chemists, and biologists worked together under the direction of a master in hydraulics, toward one common end—the promotion of the public health."[2]

Tell-tale typhoid

In the last quarter of the 19th century in the U.S., typhoid fever—also called enteric (intestinal) fever—struck about one person in six.[3] The now-forgotten dreaded disease was painful, debilitating, and protracted. After two weeks of severe frontal headaches, backaches, nosebleeds, diarrhea, and a general loss of strength, the actual fever began. Rising in the night and falling in the morning, during the next few weeks the fever gradually climbed to above 104°F, sometimes causing delirium. A rosy spotted rash spread across the abdomen. The victim suffered dry coughing as the mucus membranes became dry, brown, and coated, emitting a musty stench so strong it attracted flies. The acute phase lasted four-to-six weeks, leaving the patient emaciated; full recovery took up to half a year, with a high risk of relapse. That's assuming the victim recovered: about 10 percent died of perforated intestines, secondary pneumonia, or other complications.

Before Louis Pasteur laid the foundations of the germ theory of the transmission of disease in 1877, typhoid fever seemed baffling in its ubiquity: people fell ill with it after eating shellfish, cheese, ice cream, fruits, and vegetables, or after drinking milk or water. In 1880, two German researchers (Carl Joseph Eberth and Robert Koch) independently discovered its cause to be a bacillus (a bar-shaped bacterium). Initially called *Bacillus typhosus* or *B. typhi*, today it is known to be a member of the salmonella family (yes, of food-poisoning fame) and is named *Salmonella typhi*. [Figure 1]

Typhoid is contracted just one unpleasant way: by a human ingesting the fecal matter of an infected human. Once ingested, bacilli take up residence in the small intestine, gall bladder, liver, spleen, and bone marrow and happily set about the business of multiplying. After an



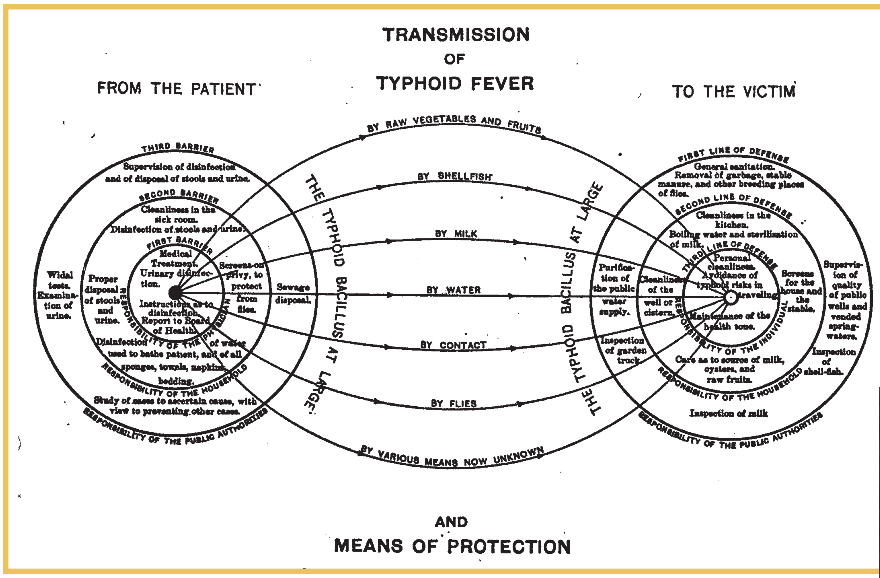


Figure 2. Typhoid fever was both infectious and contagious, having many paths of transmission that were bewildering to people before knowledge of the germ theory of transmission. Of all paths, however, the one responsible for the greatest spread of disease was drinking water contaminated with the sewage of infected humans. This diagram is the frontispiece of the classic book *Typhoid Fever: Its Causation, Transmission and Prevention* (New York: John Wiley & Sons, 1908) by consulting engineer George C. Whipple, below.

incubation period of approximately two weeks, the bacilli enter the bloodstream and spread throughout the body in a full-fledged case of typhoid fever. Until the invention of antibiotics, there was no known cure.

How could humans en masse ingest excreta from other humans? Shellfish growing in lakes or rivers into which cities discharged raw sewage were washed with contaminated effluent; cows were milked and cheese was made by people with hands not washed after emptying the privy. Flies buzzing around inadequately sealed outhouses walked on infected human *night soil* and then flew through unscreened windows into kitchens to walk on dinner, depositing bacilli. Moreover, the bacilli could live for weeks outside the human body on all kinds of surfaces, even in subfreezing temperatures. [Figure 2]

Of all transmission routes, "infected water probably caused more typhoid fever than all the other causes combined," observed consulting engineer and typhoid expert George C. Whipple in 1908.[4] Between 1890 and 1892 in Chicago, before the building of the Chicago Drainage Canal that literally reversed the flow of the Chicago River, some 4,500 people *died* from typhoid fever [Figure 3]. In the first decade of the 20th century, Pittsburgh, at the confluence of the filthy Allegheny and Monongahela rivers, lay in the throes of a chronic typhoid epidemic that annually sickened more than 5,000 of its residents—more than one percent of its population. At least half a dozen other American cities—including Cleveland, Denver, and Birmingham—suffered comparable rates.[5]

What's in a Name?

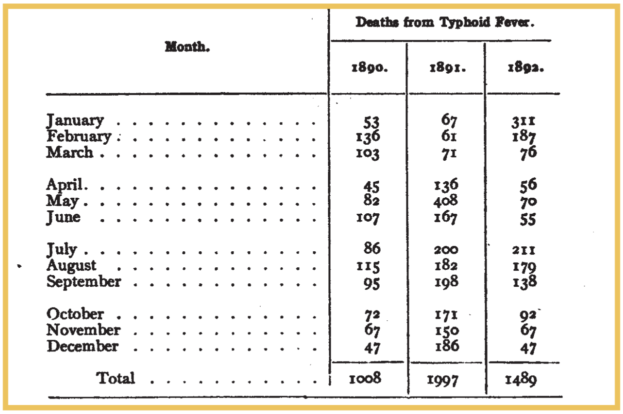
Despite a confusing similarity in name, typhoid fever has nothing to do with typhus fever. Typhus, common among men in rat-infested jails or onboard ships, is transmitted from rodent hosts to humans by arthropods (fleas, lice, ticks, chiggers); its infecting agent is a completely different parasite, *Rickettsia prowazekii.* Typhus never became a major scourge in the U.S. Similarities in the rash and other symptoms, however, led 19th-century French physician Pierre Charles Alexandre Louis to describe the human-excrement–borne fever "typhoid," meaning "typhus-like," perpetuating confusion to this day. A modern discussion of the historical confusion appears in Burke A. Cunha, M.D., "Osler on typhoid fever: differentiating typhoid from typhus and malaria," *Infectious Disease Clinics of North America* 18 (2004): 111–125. Here ends any mention of typhus in this article.

"While a high typhoid death rate is not conclusive evidence of the bad quality of the water supply, yet a low typhoid death rate is absolute proof of the sanitary excellence of the water," stated the authors of *Municipal and Private Operation of Public Utilities*. Thus, the typhoid death rate normalized to the number of typhoid deaths per 100,000 (or, in older references, 10,000) came to be called the "index of municipal sanitation." [6]

Two "fathers"

In 1861, the Commonwealth of Massachusetts approved a charter to incorporate the "Massachusetts Institute of Technology and Boston Society of Natural History." MIT's founding president, natural scientist William Barton Rogers, felt that the industrial age with its rapid scientific and technological advances needed a new form of higher education "founded on a thorough knowledge of scientific laws and principles" that upheld three main principles: "the educational value of useful knowledge ..., learning by doing, ... [and] introducing professional education at the undergraduate level."[7]

One who thoroughly embraced Rogers's founding principles was assistant professor in biology William Thompson Sedgwick (1855–1921); hired in 1883, Sedgwick quickly rose to become head of the institute's department of biology. Inspiring students to think not only rigorously but also



Month.	Deaths from Typhoid Fever.		
	1890.	1891.	1892.
January	53	67	311
February	136	61	187
March	103	71	76
April.	45	136	56
May	82	408	70
June	107	167	55
July	86	200	211
August	115	182	179
September	95	198	138
October	72	171	92
November	67	150	67
December	47	186	47
Total	1008	1997	1489

Figure 3. Some 4,500 people perished from typhoid fever in Chicago during 1890-92. Because the death rate was about 10 percent of the incident rate, those numbers suggest the number of cases was close to 50,000—meaning that during those three years about five percent of the city's population must have fallen ill. Table is from page 163 of Whipple's *Typhoid Fever*.

imaginatively, he was what today would be called an early adopter. In 1888, less than three years after courses in bacteriology began appearing in medical schools and agricultural colleges, Sedgwick began offering them to the institute's engineering students, along with biology and chemistry courses. Cautioning that "a public [water] supply is a public danger," he single-handedly created the field of non-medical sanitary science, effectively starting the world's first school of public health. For that, he has been called the "father of the modern public health movement in America."[8]

Meantime, the Massachusetts State Board of Health, founded in Boston in 1869, was reorganized in 1886 and charged with overseeing the purity of the state's inland waters, including investigating the causes and prevention of infectious diseases and examining public water supplies and sewerage. To chair the committee on water supply and sewerage, the state board appointed noted hydraulic engineer Hiram F. Mills (1836–1921), then chief engineer of the Essex Company in Lawrence, MA, a company that controlled water power to mills along the Merrimac River. Essex owned a building that Mills thought would make an excellent testing laboratory. So in 1887 the building became the Lawrence Experiment Station. Mills headed its sanitary investigations until 1915; for that, he has been called the "father of sanitary engineering in America."[9]

Mills was not only a member of the board of health; he also happened to be a member of the MIT Corporation. Thus, by 1888, Sedgwick was consulting biologist to the state board, and **Thomas M. Drown,** *Pennsylvania Alpha 1859,* an institute chemistry professor, was consulting chemist. The microscope began to be used as a tool to diagnose the bacterial content of water—a stunning advance. And a dozen talented MIT students all learned by doing hands-on interdisciplinary fundamental research at the experiment station, ultimately becoming national leaders in sanitary engineering.

Mills liked to remark that of all his discoveries, his greatest was Allen Hazen (1869–1930), a brilliant young chemical engineer who had graduated from Dartmouth's Thayer School of Engineering at the tender age of 15. Described as "tall, angular, somewhat precise, and pedantic," Hazen completed a program in chemistry at MIT in 1888 and then joined the small group of scientists at the Lawrence Experiment Station.[10]

For the next five years, Hazen focused on the hydraulics and engineering of filters for purifying drinking water, starting with (in true MIT fashion) fundamental physical principles. Although long known that water strained through stacks of sand and gravel to remove suspended material looked clearer and cleaner, early sand filters had problems with clogging and capacity. So Hazen began seeking answers to back-to-basics questions: what difference was made by the physical size of gravel or sand? whether the particles were angular or rounded? whether all sizes of particles were uniform, stratified, or mixed? whether air was bubbled through the filters? In his investigations, Hazen identified important design quantities still used by sanitary engineers, notably *effective size* and *uniformity coefficient*, and concluded that "a well-selected material is essential to successful filtration."[11]

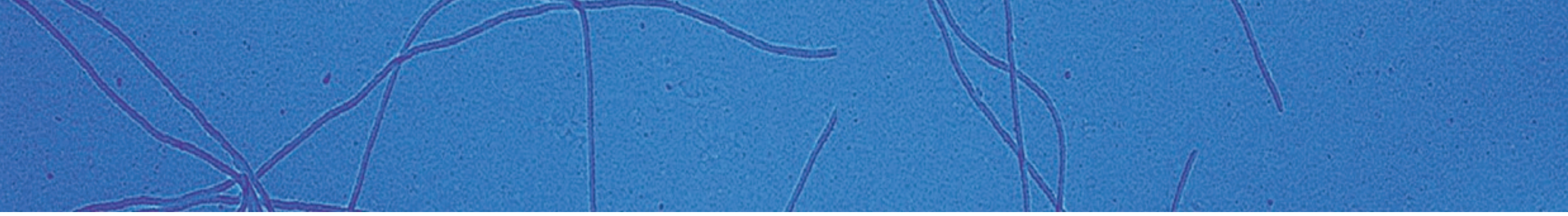
Somewhere along the way, Hazen and Mills also stumbled across a remarkable discovery: intermittent slow-sand filtration not only clarified water, but also removed 99 percent of its bacteria. Further investigation led them to a revolutionary perspective: that "filtration is not merely a physical process, but a biological phenomenon" because beneficial microorganisms were actually consuming bad bugs. In 1890, the Lawrence Experiment Station published two special reports recounting its first three years of R&D, including testing waters all over the state. The two hefty volumes, exceeding 1,700 pages, "more than any other documents issued in America influenced the thought of sanitarians and engineers on the subjects of water supply and sewage disposal."[12]

The Lowell–Lawrence epidemic

In 1890–91, a severe typhoid epidemic along the Merrimac graphically demonstrated the terrible costs of using the same water as both sewer and untreated supply.

Lowell (population 77,696) and Lawrence (population 44,654) are about nine miles apart on the banks of the Merrimac, which first flowed through New Hampshire, picking up raw sewage from various towns (including Nashua) before entering northern Massachusetts. In September 1890, a typhoid epidemic broke out in Lowell and lasted about five months, eventually totaling some 550 cases and close to 100 fatalities. Most of Lowell's water came unpurified from the Merrimac. Lowell also discharged its own untreated sewage into the river. Nine miles downstream, Lawrence also drank unfiltered river water. A few weeks after the start of Lowell's typhoid epidemic, an even more severe epidemic broke out in Lawrence. The rise, peak, and decline of the epidemics in both cities followed lockstep a month apart [Figure 4].

As biologist to the state board of health, Sedgwick was tapped to conduct a detailed investigation. His upstream bacterial counts revealed that "the proportion of sewage



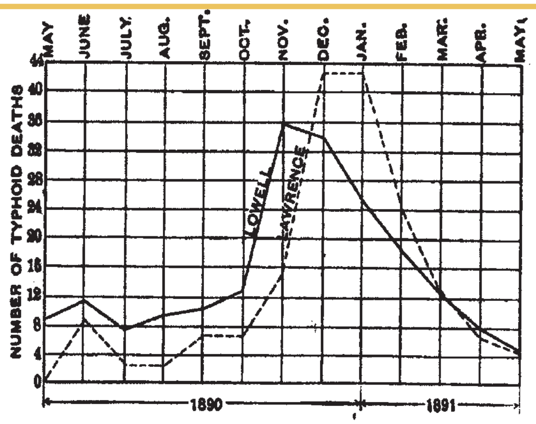


FIG. 13.

Diagram Showing the Chronological Relation between the Lowell and Lawrence Typhoid Fever Epidemics.

Figure 4. The rise, peak, and decline of the typhoid fever epidemics in Lowell, MA, and its downstream sister city of Lawrence followed each other almost exactly one month apart, strongly demonstrating causal relationship between the two. Graph is from page 153 of Whipple's *Typhoid Fever*.

that has been directly mingled with the water of the Merrimack [sic] River is, at the time when it arrives at Lowell, about one part of sewage in every 1,200 parts of the water. This is roughly equivalent to a thimbleful of sewage in every quart of city water." Meantime, Mills conducted experiments that demonstrated typhoid germs could remain alive in the river at 35°F to 45°F while floating nine miles to Lawrence, a journey of likely fewer than 10 days. He also found that the typhoid death rates in Lawrence and Lowell were regularly the two highest in the entire state, double even that of much larger Boston. Sedgwick concluded his report: "In view of all the foregoing facts I find myself compelled to report to your Honorable Board my firm conviction that there is danger, both constant and grave, in the water of the Merrimack River at Lowell."[13]

Amazingly, Lowell appears not to have taken action as a result of the report. But Lawrence city fathers were horrified and put up a princely $67,000 for a 2.5-acre slow-sand filter for purifying Lawrence's drinking water. For Mills, Sedgwick, Drown, Hazen, and the rest of the experiment station, the project was fundamentally a giant full-size proof-of-concept beta test of both new science (bacteriology) and new technology (Hazen's findings about materials) using an entire town.

The results were immediate, dramatic, and gratifying. The Lawrence filter began running on September 20, 1893. The typhoid death rate—which had averaged 113.1 per 100,000 during 1888-92 before its introduction—plummeted to 25.4 during 1894-98 after filtration [Figure 5] (and half the remaining typhoid cases were traced to other sources of infection). The Lawrence filter was hailed as a triumph nationally and internationally and inspired the design of far larger filtration plants for Albany, Washington, Philadelphia, and Providence.[14]

Engineers: 2, typhoid: 0

By 1900, hundreds of municipal water filters of various designs had been installed around the U.S., covering at least six percent of the population. By 1910, some 8 million Americans—more than 22 percent of the urban population—were drinking filtered water. Wherever water filtration was introduced, the typhoid death rate dropped.[15] [Figure 6]

Slow-sand filters were most practical with relatively clear waters (such as those of New England), but mechanical filters of various designs were more resistant to clogging in turbid waters, such as those of the muddy Mississippi River. Mechanical filters, however, tended to be less effective in eliminating bacteria.

Enter chlorination. Throughout the 19th century, it was known that hypochlorite of lime (basically powdered chlorine bleach) was effective in deodorizing drinking water or sewage. But the idea of using hypochlorite to disinfect public water supplies was not seriously considered until the fall of 1908, after George A. Johnson of the New York engineering firm of Hering & Fuller tried it to purify polluted feed water for cattle at the Union Stock Yards in Chicago. The bacteria count dropped so spectacularly that Johnson then installed equipment at Boonton, NJ, for the continuous chlorination of unfiltered drinking water to Jersey City.

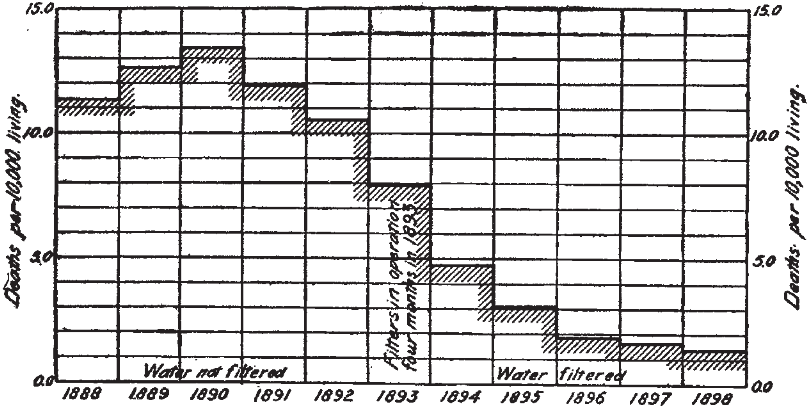


FIG. 16.—TYPHOID FEVER IN LAWRENCE, 1888 TO 1898.

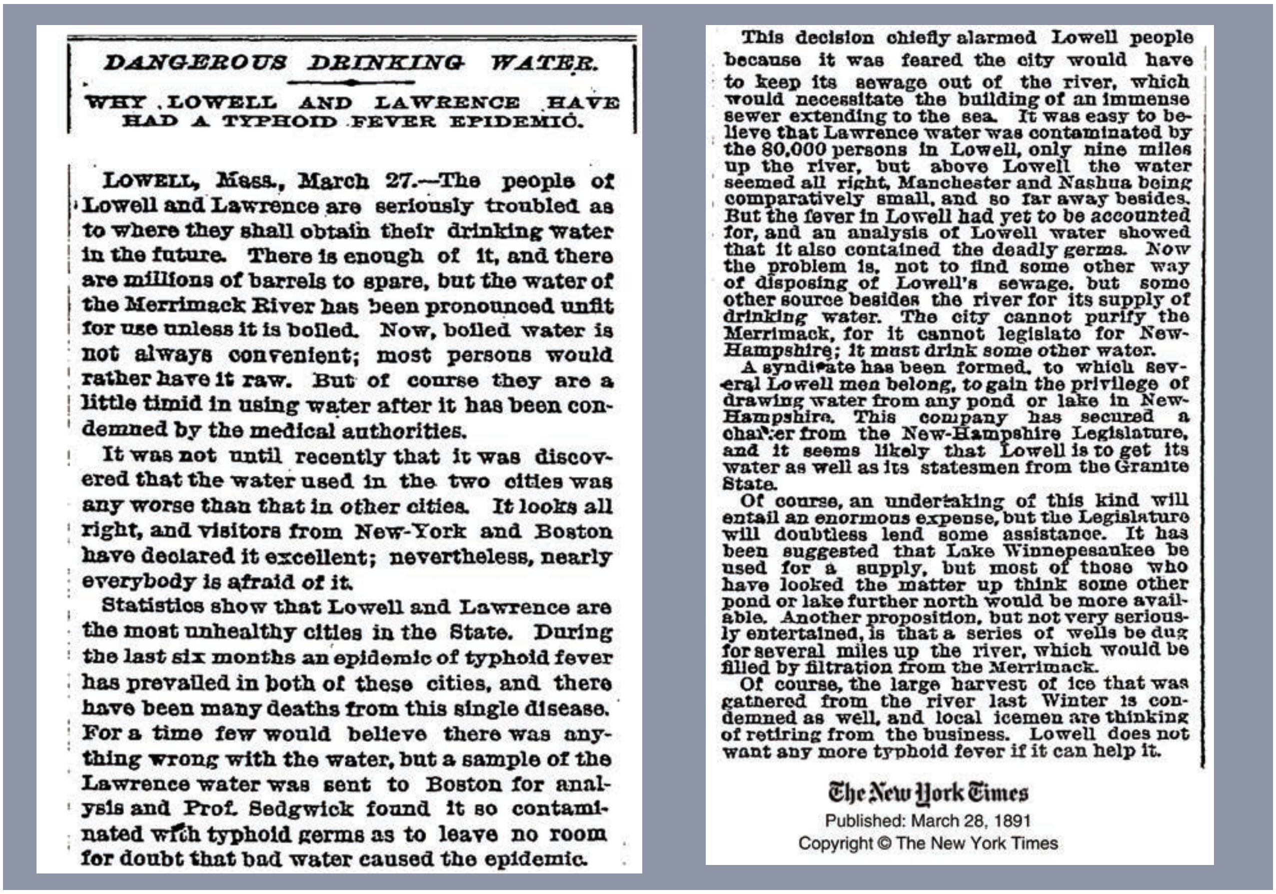
Figure 5. The effect of the slow-sand filter in eliminating typhoid bacilli from Lawrence's water supply is clearly shown in the death rates before and after its installation in 1893. Chart is from Allen Hazen, *The Filtration of Public Water-Supplies* (New York: John Wiley & Sons, 1900), 105.

Chlorination seemed almost a miracle: so little bleaching powder was necessary to purify drinking water that the process was cheap; most cities used between 5 and 12 pounds per million gallons, although Bubbly Creek was treated with 45 pounds per million gallons.[16] Its successes were so widely publicized that within three years Cincinnati, Columbus, Harrisburg, Hartford, Milwaukee, Nashville, New York City, Omaha, Philadelphia, Pittsburgh, and St. Louis began chlorinating their water supplies, whether filtered or not.

But what was the optimal dose of chlorine for water? In some cities, residents complained about the taste of chlorinated water. Also, chlorine was poisonous to humans as well as bacilli, so the best amount was clearly the tiniest amount that was effective against bad bugs. Enter a pioneer in the second generation of great water sanitarians, **Abel Wolman,** *Maryland Alpha 1915*, who graduated from Johns Hopkins University with bachelor's degrees in pre-med (1913) and in civil engineering (1915). Wolman and a chemist colleague (Linn H. Enslow) solved the problem in 1919; they developed a test to measure chlorine absorption and bacterial count, as well as acidity and factors important to taste and purity. They also invented a method for standardizing doses of chlorine to municipal water supplies—a method still in use today.[17]

As early as 1921, typhoid fever expert Whipple declared victory: "The typhoid fever death-rates [in cities] are becoming so low that they can no longer be regarded as sufficient to measure the healthfulness of a water supply."[18] By 1931, typhoid posed a risk primarily only in rural water supplies. By 1942, the typhoid death rate nationwide had fallen below 5 per 100,000; by 1957, it was under 1, where it has remained ever since—all without immunizations or medical intervention.[19]

So when you turn the tap and fill a glass with clear, sparkling drinking water blessedly free of sewage-borne typhoid bacilli, toast a host of engineers.



DANGEROUS DRINKING WATER.

WHY LOWELL AND LAWRENCE HAVE HAD A TYPHOID FEVER EPIDEMIC.

LOWELL, Mass., March 27.—The people of Lowell and Lawrence are seriously troubled as to where they shall obtain their drinking water in the future. There is enough of it, and there are millions of barrels to spare, but the water of the Merrimack River has been pronounced unfit for use unless it is boiled. Now, boiled water is not always convenient; most persons would rather have it raw. But of course they are a little timid in using water after it has been condemned by the medical authorities.

It was not until recently that it was discovered that the water used in the two cities was any worse than that in other cities. It looks all right, and visitors from New-York and Boston have declared it excellent; nevertheless, nearly everybody is afraid of it.

Statistics show that Lowell and Lawrence are the most unhealthy cities in the State. During the last six months an epidemic of typhoid fever has prevailed in both of these cities, and there have been many deaths from this single disease. For a time few would believe there was anything wrong with the water, but a sample of the Lawrence water was sent to Boston for analysis and Prof. Sedgwick found it so contaminated with typhoid germs as to leave no room for doubt that bad water caused the epidemic.

This decision chiefly alarmed Lowell people because it was feared the city would have to keep its sewage out of the river, which would necessitate the building of an immense sewer extending to the sea. It was easy to believe that Lawrence water was contaminated by the 80,000 persons in Lowell, only nine miles up the river, but above Lowell the water seemed all right, Manchester and Nashua being comparatively small, and so far away besides. But the fever in Lowell had yet to be accounted for, and an analysis of Lowell water showed that it also contained the deadly germs. Now the problem is, not to find some other way of disposing of Lowell's sewage, but some other source besides the river for its supply of drinking water. The city cannot purify the Merrimack, for it cannot legislate for New-Hampshire; it must drink some other water.

A syndicate has been formed, to which several Lowell men belong, to gain the privilege of drawing water from any pond or lake in New-Hampshire. This company has secured a charter from the New-Hampshire Legislature, and it seems likely that Lowell is to get its water as well as its statesmen from the Granite State.

Of course, an undertaking of this kind will entail an enormous expense, but the Legislature will doubtless lend some assistance. It has been suggested that Lake Winnepesaukee be used for a supply, but most of those who have looked the matter up think some other pond or lake further north would be more available. Another proposition, but not very seriously entertained, is that a series of wells be dug for several miles up the river, which would be filled by filtration from the Merrimack.

Of course, the large harvest of ice that was gathered from the river last Winter is condemned as well, and local icemen are thinking of retiring from the business. Lowell does not want any more typhoid fever if it can help it.

The New York Times

Published: March 28, 1891

Partial references:

[1] David Cutler and Grant Miller, "The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States," *Demography 42* (1): 1–22, February 2005, 1.

[2] William T. Sedgwick, *Principles of Sanitary Science and the Public Health, with Special Reference to the Causation and Prevention of Infectious Diseases* (New York: The Macmillan Company, 1922), 144.

[3] George C. Whipple, *Typhoid Fever: Its Causation, Transmission and Prevention* (New York: John Wiley & Sons, first edition, 1908), 128.

[4] Whipple, 132.

[5] Whipple, 162–165. Also the table "Typhoid Fever Death-Rates and Water-Supplies of Cities" in Allen Hazen, *The Filtration of Public Water-Supplies* (New York: John Wiley & Sons, 1900), 211–212.

[6] *Municipal and Private Operation of Public Utilities: Report to the National Civic Federation Commission on Public Ownership and Operation. In Three Volumes.* Part I - Volume I: General

Conclusions and Reports. New York: National Civic Federation, 1907, 141. Also Albert H. Hooker, *Chloride of Lime in Sanitation* (New York: John Wiley & Sons, 1913), 12.

[7] Warren K. Lewis, et al., *Report of the Committee on Educational Survey to the Faculty of the Massachusetts Institute of Technology,* MIT Press, December 1949, 8.

[8] C.-E.A. Winslow, "William Thompson Sedgwick 1855–1921," *Journal of Bacteriology 6* (3): 255–262, May 1921. See also Winslow "There Were Giants in Those Days," *American Journal of Public Health* 43 (6 Part 2): 15–19, June 1953 and Sedgwick, *Principles,* 221.

[9] Massachusetts Historical Commission, *MHC Reconnaissance Town Survey Report,* Lawrence, 1986; Updated, 1997, 4.

[10] Winslow, "Giants," 16. Also "The State Board of Health Reorganized (1886–1914)," in George Chandler Whipple, *State Sanitation: A Review of the Work of the Massachusetts State Board of Health,* (Cambridge: Harvard University Press, 1917) vol. I, 81.

[11] An important text that brought European sand-filtration technology to the U.S. was James P. Kirkwood, *Report on the Filtration of River Waters, for the Supply of Cities, as Practiced in Europe ...* (New York: D. Van Nostrand, 1869). Allen Hazen, "Some Physical Properties of Sand and Gravels, with Special Reference to their Use in Filtration," *State Sanitation,* vol. II, 248.

[12] "The Lawrence Experiment Station and the State House Water and Sewage Laboratories," *State Sanitation,* vol. I, 144. "The State Board of Health Reorganized (1886–1914)," *State Sanitation,* vol. I, 82. The two-volume work is *Examinations by the State Board of Health of the Water Supplies and Inland Waters of Massachusetts, 1887–1890* (Boston: Wright and Potter, 1890).

[13] Prof. W.T. Sedgwick, "An Epidemic of Typhoid Fever in Lowell, Mass. Abstract of a Report upon the Sanitary Condition of the Water-Supply to the Lowell Water Board, April 10, 1891," *The Boston Medical and Surgical Journal 124* (17): 399, April 23, 1891, and 124 (18): 430, April 30, 1891. Hiram F. Mills, "Typhoid Fever in its Relation to Water Supplies," in George Chandler Whipple, *State Sanitation,* vol. II, 136.

[14] Neither any slow-sand filter nor any mechanical filter in Lowell appears in the five pages of detailed tables published in Hazen, *Filtration* 244, 247–250. Hazen gives a detailed description and account of the early operation of the Lawrence filter on pages 100-106.

[15] George A. Johnson, "Hypochlorite Treatment of Public Water Supplies: Its Adaptibility [sic] and Limitations," *Journal of the American Public Health Association 1* (8): 562–574, August 1911. Frederic P. Gorham, "The History of Bacteriology and its Contribution to Public Health Work," in Mazÿck P. Ravenel, *A Half Century of Public Health: Jubilee Historical Volume of the American Public Health Association* (New York: American Public Health Association, 1921), 80. George A. Johnson, "The Typhoid Toll," *Journal of the American Water Works Association 3* (2): 249–326, June 1916.

[16] Hooker, 14–15.

[17] M. Gordon Wolman, "Abel Wolman 1892–1989," *Biographical Memoirs of the National Academy of Sciences 83* (2003): 3–18. The 1919 paper announcing the chlorination-standardization method was by Abel Wolman and Linn H. Enslow, "Chlorine Absorption and the Chlorination of Water," *The Journal of Industrial and Engineering Chemistry 11* (3): 209–213, March 1919. Like Mills, Wolman has also been called the "father of sanitary engineering," and in 1948 he received the William T. Sedgwick medal of the American Public Health Association (full circle).

[18] George C. Whipple, "Fifty Years of Water Purification," in Ravenel, *Half Century,* 180.

[19] Abel Wolman and Arthur E. Gorman, "Water-Borne Typhoid Fever Still a Menace," *American Journal of Public Health 21* (2):115–129, February 1931. Also Table Series B 291–304 "Rates Per 100,000 Population for Specified Reportable Diseases: 1912 to 1970," U.S. Department of Commerce, Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1970,* Bicentennial edition, 1976, Part 1, 77.

[20] Hiram F. Mills, "Typhoid Fever in its Relation to Water Supplies," in *State Sanitation,* Vol. II, 131.

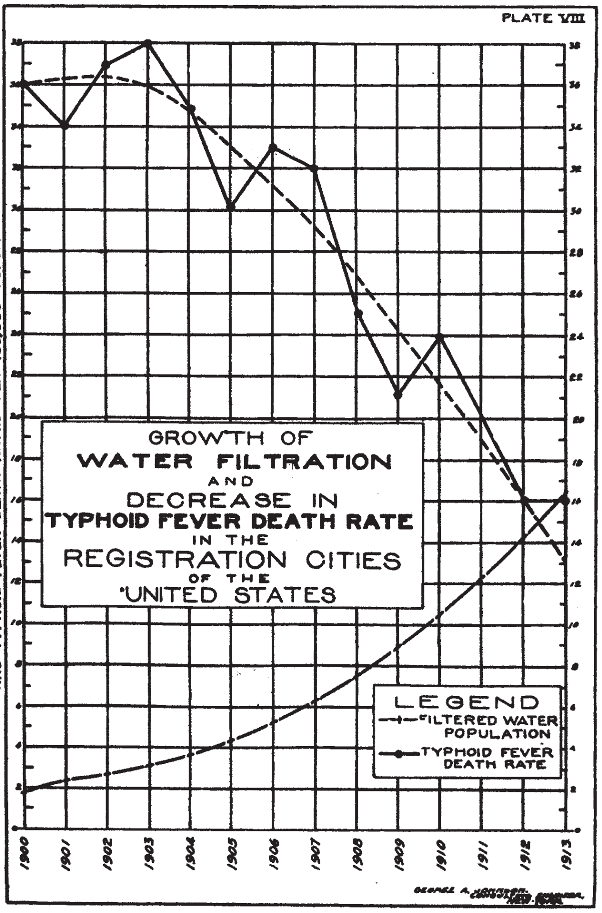


Figure 6. Typhoid fever declined everywhere in the U.S. where public water supplies were filtered. Chart appears in George A. Johnson's, "The Typhoid Toll," *Journal of the American Water Works Association* 3(2):*308,* June 1916.

Trudy E. Bell (*t.e.bell@ieee.org*) is shown here with the pumps inside the Crown filtration (water works) plant in Westlake, OH, which she visited as part of her research for this article. A former editor for *Scientific American* and *IEEE Spectrum,* she earned an M.A. in the history of science and American intellectual history from New York University in 1978; during spring 2010, she is a presidential fellow in the SAGES program at Case Western Reserve University. Author of *The Great Dayton Flood of 1913* (Arcadia, 2008), *Weather* (part of the Smithsonian Science 101 set, HarperCollins 2007), and nine other books, this feature is her 11th for The Bent since 2002.