A Public Health Giant Step: Chlorination of U.S. Drinking Water

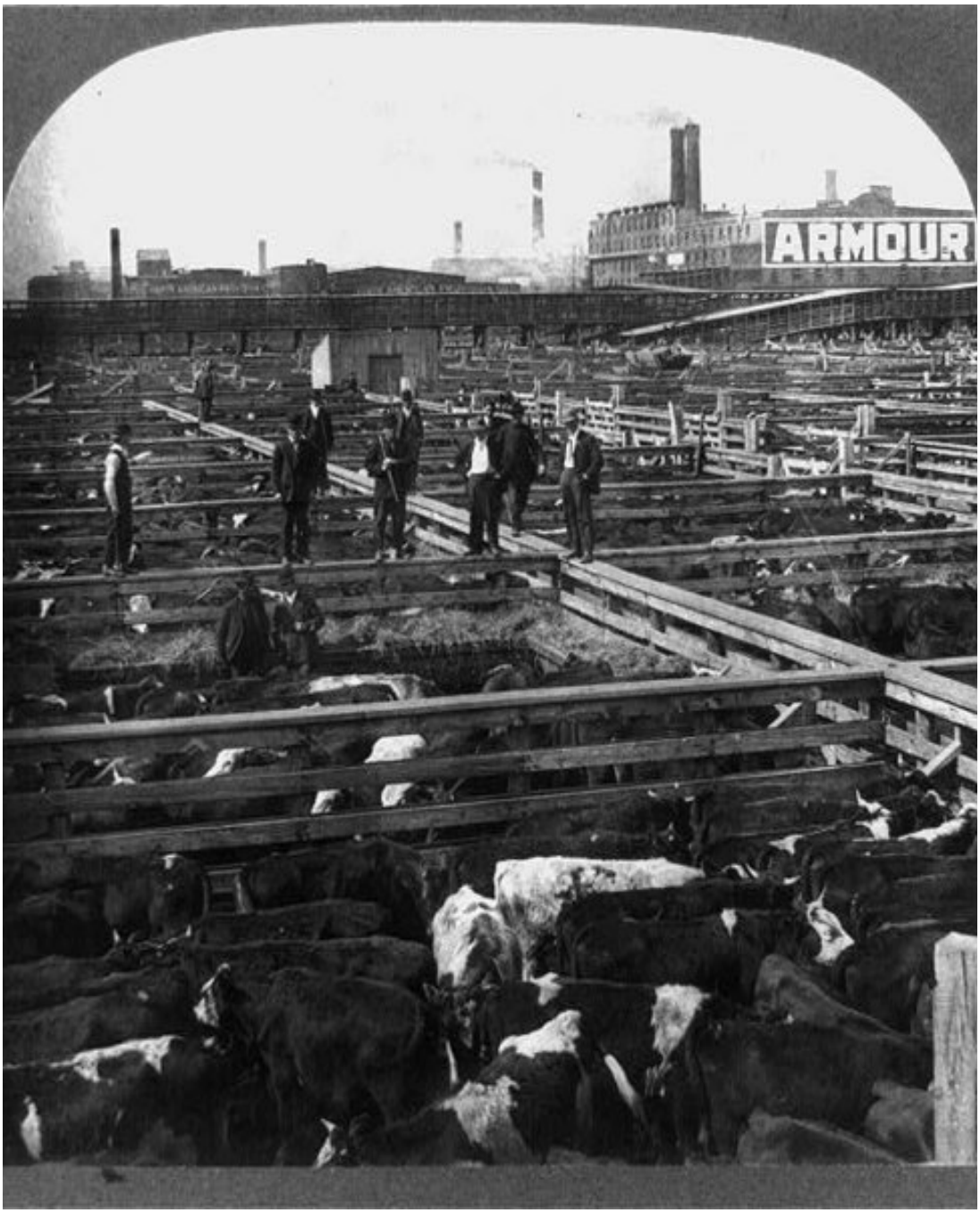
A century ago, in 1908, chlorine chemistry's germ-defeating properties were demonstrated in drinking water in two very different settings in the United States. First, chlorination transformed animal feed water, drawn from a highly polluted stream in Chicago's Union Stockyards, into a product that exceeded the purity of city water. Days later, in Jersey City, chlorinated water was supplied for the first time on a permanent basis to a large U.S. municipality. The results included a dramatic decline in the local typhoid fever rate and a water supply that, according to a 1928 sanitary engineering report, "is not only of a high sanitary quality, but…it compares favorably with the best in the country."[1]

Good news traveled quickly and within a decade, drinking water chlorination spread to nearly every large city in the country. It has been called "a tremendous boon in the safeguarding of public health all over the world and is probably the most important and efficient sanitary measure of protection ever introduced[2]."

This article describes two historic milestones in the events leading to widespread chlorination of U.S. drinking water.

Chicago's Union Stockyard

[1] Report of W.C. Mallalieu, Sanitary Engineer consultant, New York City, 1928.
[2] Report of Daniel D. Jackson, Sanitary and Chemical Engineer, Executive Officer of the Dept. of Chemical Engineering of Columbia University, November, 1928.



Chicago's Union Stockyards
Circa 1909

It was late summer, 1908, and there was a problem in Chicago's Union Stockyards: the livestock were not gaining weight. The water, it was suspected, was the problem. The stockyards supplied filtered drinking water to the animals from a nearby creek. But the animals only gained weight when they were given Chicago city water. Unfortunately, diverting city water was illegal and Chicago

officials had sued the stockyards for poaching municipal water. Something had to be done.

Water Unfit for Man or Beast

The Chicago Union Stockyards was the bustling hub of the U.S. meat trade at the dawn of the 20th century. Built in 1864 by a consortium of nine railroad companies, the stockyards served as a focal point of commerce between East and West. By 1900, the Union Stockyards comprised 475 acres imprinted with 50 miles of roads and bordered by 130 miles of railroad track. Meatpacking companies established operations in the "yards" and employed more than 25,000 people, mostly immigrants[3], working in conditions described as appalling in literature such as Upton Sinclair's *The Jungle*.

Conditions were not very good for the animals either. The creek that supplied water to the livestock was the nearby meat-waste-polluted tributary of the Chicago River known as Bubbly Creek. "Bubbly" it was—from the gases given off from decaying animal parts. The creek oozed methane and hydrogen sulfide, releasing a rotten egg odor. A filtration plant, built on the south bank of the Creek in 1907, cleared the water of particles and debris before it was distributed to the animal drinking troughs. Copper sulfate was added to the water at the treatment plant as a germicide, but it would have removed only algae. The livestock failed to thrive on filtered Bubbly Creek water.

Chlorination Saves the Day

In late summer of 1908, George A. Johnson of the New York firm of Hering & Fuller was summoned by the stockyards to test the quality of Bubbly Creek treated water. At the treatment plant, Johnson pronounced the filtration operation satisfactory, but noted the bacterial count of a water sample soared in the period following its drawing. This, he concluded, was due to the high organic matter content of the water. Between September 3 and September 17, Johnson tested a germicide known as "chloride of lime" in the filtered water of Bubbly Creek. The results reversed the original water quality situation: it was reported that filtered and chlorinated Bubbly Creek water had become cleaner than Chicago municipal water!

The addition of chlorine disinfection of Bubbly Creek water solved the livestock drinking water problem in the Union Stockyards. In later years Johnson would use the example of Bubbly Creek to demonstrate that filtration alone, without disinfection, is insufficient for treating drinking water.

[3]Chicago Historical Society, "Slaughterhouse to the world," on-line: http://www.chicagohs.org/history/stock.html, accessed 3-24-08.

Jersey City, New Jersey

View of Jersey City, circa 1910
Photo courtesy of The New Jersey Room
Jersey City Free Public Library

In 1908, Jersey City, located on the west bank of the Hudson River across from Lower Manhattan, was a busy industrial and railroad center and home to approximately 200,000 residents. For several years following the construction of a new water supply system in 1904, the city had been at odds with the local water company over the quality of the municipal drinking water. Jersey City had sued the Jersey City Water Supply Company for failing to meet a contract requirement, namely that "the water to be furnished must be pure and wholesome for drinking and domestic purposes…."[4]

Like all developed American cities of the day, Jersey City had battled typhoid fever, which can be transmitted through unsanitary water, since at least the late 1880s. In 1895 the typhoid death rate had reached "the startling figures of 80 per 100,000 population."[5] In that year the water supply, taken from the Passaic River, was cut off and a temporary supply tapped from the Pequannock River. By 1898,

[4] J.L. Leal (1909), The sterilization plant of the Jersey City Water Supply Company at Boonton, N.J., American Water Works Association Conference, Milwaukee, (June 8).
[5] From a lecture delivered by E.W. Harrison, Civil Engineer, before the Historical Society of Hudson County, New Jersey, 1909.

the typhoid fever death rate had dropped to 40.6 per 100,000[6], which was better, but still unacceptable.

In 1904, Jersey City began receiving untreated drinking water from the Boonton Reservoir, an impoundment of the Rockaway River 23 miles west of the city. The water was delivered from Boonton to two local reservoirs through a series of steel pipes and masonry conduits. High bacterial counts were noted a few days per year, generally associated with high water and flooding. In 1906 a typhoid fever rate of 21.4 per 100,000 was recorded.

Water Issues on Trial

A New Jersey court offered the opinion on May 8, 1908 that purification of Jersey City water could be achieved at great expense by means of a filter plant, but because such a facility had not been part of the original plans, a filter plant could be dismissed from consideration unless "indispensably necessary" to complete contract obligation. Based on evidence given the city, the court said that the situation could be remedied if sewers and sewage disposal works were built for communities in the watershed. The city would hold fast to the opinion that the water company should construct sewer works.

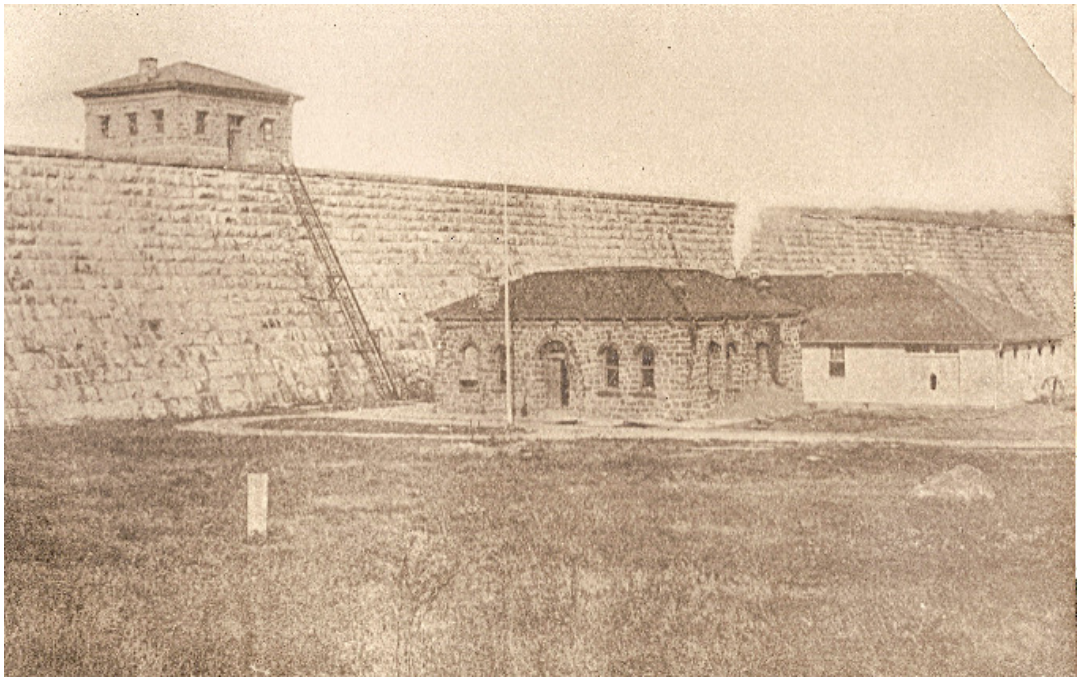
An advisor to the water company, Dr. John L. Leal, did not agree that these expensive measures would be effective. He believed, as he later told members of the American Water Works Association (AWWA), that "…by far the greater percentage of bacterial and *B. coli* found at the point of delivery in Jersey City was due more to the washings of soil, roads, streets, manured fields, etc., than from any sewage contamination…" He had a novel, inexpensive solution in mind for ridding Jersey City drinking water of bacteria, and on his advice, the court gave the water company 90 days to suggest its own method of meeting the contract requirements.

Doctor Leal Prepares a Disinfection Plan

Leal had experimented since the late 1890s with "electrolytic solutions of salt." Salt, sodium chloride, is essentially split into chlorine gas and a sodium compound when electricity is passed through salty water. The doctor had also investigated liquid bleach, sodium hypochlorite, a compound of sodium, oxygen and chlorine. When applied to water, both chlorine gas and bleach form hypochlorous acid, a strong disinfectant. Leal's idea was to apply a chlorine disinfectant to Jersey City water to destroy any bacteria present. He had 90 days to implement his plan.

[6] Figure from Jersey City historical records supplied by United Water Jersey City.

Unable to find the appropriate electrolytic equipment that would yield chlorine gas or liquid bleach, Leal decided to use powdered chloride of lime, the same disinfectant used by Johnson in Chicago. The necessary treatment apparatus was designed by Mr. George Warren Fuller of Hering & Fuller. Fuller created a system to add dissolved chloride of lime into the water supply as it left the Boonton Reservoir and flowed to the city. On September 26, 1908, the chlorination of Jersey City water began with George A. Johnson of Hering &



Gate Houses and Chlorination Plant at Boonton Reservoir *circa* 1908
(The chlorination plant is the building at the center.)

Photo courtesy of Keith Wood, Watershed Superintendent,
United Water Jersey City

Fuller, veteran of Bubbly Creek, in charge of operations. September 26, 2008 marks a century of continuous chlorination for this pioneering water system.

The Struggle for Acceptance

Despite very low bacteria levels in city water following the introduction of chlorination, newspaper accounts from the time show that the city would continue to argue for sewer works in the watershed. The litigation would prove to be a "severe drain on the taxpayers," according to a newspaper account in May, 1909. A May 5 article in *The Evening Journal*[7] titled, "Jersey City Water Gets Hard Knocks," states, "The city claims the works as now built need intercepting sewers to make them acceptable. The chemical treatment of the Boonton water as tried

[7] In 1910, *The Evening Journal* became *The Jersey Journal*.

by the water company has not proved satisfactory, so the city claims." Testimony reported pits the city against the Jersey City Water Supply Company, with the two sides disputing sampling results at various locations in the watershed. The city battled on, convinced that the water company should furnish sewers.

The Battle Goes to Milwaukee

While the court case was pending, the stakes for the city were so high that worried city commissioners followed Dr. Leal, George Warren Fuller and George Johnson to Milwaukee for the 1909 AWWA annual meeting. Reporting on the planned journey, The June 2 *Evening Journal* headlines claimed "Water Board to Watch Dr. Leal: Commissioners Start for Milwaukee Saturday Night to Prevent National Convention Indorsement *[sic]* of Chemical Treatment of Boonton Water." The newspaper was very clear about the purpose of the commissioners' attendance at the meeting, stating:

> *"One of the objects of the trip is to keep an eye on Dr. John L. Leal and Expert George Johnson of the East Jersey Water Company…Dr. Leal is a good talker and able scientist and some of the Jersey City officials are wondering whether the doctor will try to get the convention's indorsement [sic] of his bleaching powder process. It is asserted that if the convention were to indorse the chemical process it would be a great feather in the East Jersey's cap."*

The presentations of Leal, Fuller and Johnson to the AWWA membership in June, 1909 record for all time the circumstances and details of the first large-scale, continuous implementation of drinking water chlorination in the United States. In this national gathering of water professionals, the argument for chemical disinfection was elevated to a level of prominence needed for eventual public acceptance, beyond the realm of local politics.

Each of the presenters described his contribution to the project. Dr. Leal related the legal history of the water company and his concept for chlorine disinfection; George Warren Fuller explained the construction and design of the "sterilization plant;" and George Johnson discussed the methods of operation of the plant.

Data presented by the three men lent support to the effectiveness and low cost of chlorination. Water treated with very small applications of chlorine indicated very low levels of bacteria. Johnson revealed the cost of chlorine treatment to be 14 cents per million gallons, a mere $5.60 per day for Jersey City's 40 million gallons daily usage.

The Boonton Plant is Approved and Public Health is the Winner

On May 9, 1910, almost one year after the momentous AWWA Milwaukee meeting, the Boonton Plant was approved by a "special master in chancery" of the court. By the 1920s, chlorination was well-established as the primary means of disinfecting drinking water.

Drinking Water Chlorination Spreads across America

M.N. Baker in his 1948 book, "The Quest for Pure Water[8]," states, "Nothing in the field of water purification came into use as rapidly and as widely, once it got a good start, as chlorination". Baker credits its adoption at Jersey City's Boonton Reservoir as the impetus for its subsequent widespread use. By 1941, Baker reported 4,590 out of 5,372 [85 percent] treatment plants used chlorine for disinfection.[9] Reliance on chlorine disinfectants remains high today, according to AWWA data.

In his June, 1909 report to the AWWA, Dr. Leal said he believed one of the most important uses of chlorination would be "in conjunction with filtration." His words were prophetic: in 1997 *Life* magazine declared, "The filtration of drinking water plus the use of chlorine is probably the most significant public health advance of the millennium."

A 2004 statistical study of disease rates in cities found clean water to be the reason for rapid declines in urban death rates during the late 19th and early 20th Centuries. The study concludes that clean water was responsible for "nearly half of the total mortality reduction in major cities, three-quarters of the infant mortality reduction, and nearly two-thirds of the child mortality reduction." The study puts forth a striking finding -- that chlorination and filtration reduced typhoid fever by 91percent within 5 years, leading to its near-eradication by 1936.

Leal predicted the use of chlorine disinfectants during water supply emergencies "where water supplies have become infected and where it is impossible to cease using such supplies." He called such practical applications "a great advance in the science of water purification." Leal continued to say that "it is so cheap, so easy and quick of application, so certain in its results, and so safe, that it seems to me to cover a broader field than does any other system of water purification yet used. It cannot but conduce to the economic and physical benefit of mankind."[10]

Leal's words resonate today. While safe drinking water technology is the norm in the developed world, some 1.2 billion people in the developing world lack access to safe water. Sadly, most of the victims of waterborne diseases are children

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[8] Baker, M.N. (1948). The Quest for Pure Water: The history of water purification from the earliest records to the Twentieth Century, American Water Works Association, Inc., New York.
[9] McGuire, M. (2006). Eight revolutions in the history of U.S. drinking water disinfection, Journal of the American Water Works Association (March).
[10] J.L. Leal (1909).

under the age of five. Access to safe water technology not only reduces disease, but also provides a range of economic benefits for a community. The World Health Organization (WHO) has reported that global investments in water access yield direct and indirect benefits that far exceed the associated costs. Where piped water supplies are not currently available, simple technologies to treat water in individual households can provide immediate benefits. WHO reports, “Household approaches, including treatment with chlorine-based disinfectants, have been shown to be extremely cost effective, rapidly deployable, and can lead to significant health gains.”

The history of U.S. drinking water chlorination began in the dusty stockyards of Chicago and in thriving Jersey City, with its view of the back of the Statue of Liberty. In these two unlikely places, Fuller, Leal and Johnson demonstrated the power of chemistry over waterborne germs, igniting a revolution that continues to yield public health benefits 100 years later.