New York Legionella Regulations: Are They Missing The Boat?

by Sarah Ferrari

Abstract

A large outbreak of Legionnaires' disease in the Bronx in 2015 prompted NYC to enact law and NYS to propose emergency regulations on the registration and maintenance of cooling towers. This paper describes the fundamental characteristics of point sourced vs. potable water sourced outbreaks and discusses the Bronx outbreak from those perspectives. Ultimately a case is made that these new regulations will not have a measurable impact on reducing the incidence of Legionellosis. Rather, more detailed and open-minded investigations of future outbreaks, including investigation of potential potable water sources, are called for to inform appropriate regulations and disease prevention activities.

Sarah Ferrari

Introduction

Legionnaires' disease (LD) is a severe form of pneumonia which is contracted by inhaling or aspirating water droplets containing *Legionella* deeply into the lungs. For many years it was believed the disease could be transmitted only by large equipment which emits aerosols or by equipment designed to aerosolize. Thus spas, decorative fountains, grocery misters, spray humidifiers, cooling towers and other aerosol sources were the only water systems investigated when an outbreak occurred. In the early 1980s investigations of potable water systems in hospital outbreaks indicated that the potable water is also a vector in disease transmission, either via aspiration of *Legionella* from the mouth into the lungs [1] or via inhalation of droplets emitted by sinks and showers. It now appears that many LD outbreaks were initially blamed on cooling towers due to a "detection bias" that has not been widely recognized, and that these outbreaks were actually caused by potable water issues. In more recent years it has been found that the **primary source** of hospital-acquired Legionnaires' disease is potable water [2].

In the United States there have been requirements to address *Legionella* in hospital potable water systems from the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO), Allegheny County (Pittsburgh), Maryland, New York, and others; however, until recently there have been no similar mandates in the United States for cooling towers. Although not mandated, many industrial groups such as CTI, ASHRAE, and AWT have published best practice guides that describe methods for maintaining equipment to minimize the risk of Legionellosis.

More than fifty *Legionella* species have been identified, but not all have been linked to disease. *Legionella pneumophila* serogroup 1 is the most virulent strain causing the majority of infections[3]. Virulence varies not only between strains and their subtypes but can also vary within a particular cell. There are two major phases to the life cycle; a non-pathogenic vegetative phase and a virulent transmissive phase. The concepts of 'infectious dose' or of 'relative *Legionella* concentrations' discussed within this paper pertain only to the virulent, or infectious, form of the bacteria.

The vast majority of LD occurs as apparently isolated cases. Of cases reported to the CDC, 96% are classified as sporadic and are not typically investigated[4]. A cluster of cases is classified as an outbreak when two or more people are exposed to *Legionella* and get sick in the same place at about the same time. Recognized outbreaks of LD are rare; but when they occur, they provide opportunities to understand the epidemiology of the illness and improve prevention strategies. This opportunity is wasted if the extensive data that is generated during an outbreak is not evaluated impartially.

The recent outbreak in the South Bronx has resulted in New York City enacting a local law[5] on the registration and maintenance of cooling towers in the city. Also, the State of New York has proposed emergency regulations for the registration and maintenance of cooling towers state-wide[6]. As more facts have emerged, it appears that the hastily prepared emergency regulations have fallen victim to the "detection bias" referred to in the first paragraph above and that authorities have not only squandered an opportunity to expand our understanding of the disease but imposed regulations and cost on cooling tower owners that have little chance of reducing the incidence of disease.

This paper will describe the outbreak in the Bronx that instigated these regulations. While a specific cooling tower was identified as the source of the original outbreak, two subsequent outbreaks occurred. Potable water in the building where people lived was positively identified as the source for second outbreak. Two months after the third outbreak ended a cooling tower was identified as the source, even though all of the cooling towers in the area had been recently cleaned in accordance with the newly enacted NYC laws.

The Bronx outbreak and regulatory response has many similarities to a French outbreak in the winter of 2003-2004. In Pas-de-Calais a large outbreak was attributed to a cooling tower and resulted in the promulgation of regulations for the registration and maintenance of cooling towers. The inconsequential result of those regulations on the reduction of the incidence of disease will also be described in this paper.

Outbreak Characteristics

Aerosol Point-Source

There have been many Legionnaires' disease outbreaks traced to an aerosolized point source of the bacteria. Point sources of aerosols include decorative fountains, spas, grocery misters, and cooling towers. Investigation of these outbreaks typically reveals a close relationship between time spent near the source and incidence of infection. A dose-response relationship between exposure and illness has been demonstrated in numerous carefully investigated studies. This is particularly true for indoor sources where proximity to the aerosol source has been identified as an essential factor for infection. For cooling tower sources the same relationship exists, i.e., a close correlation between proximity to the source and incidence of disease. However, for some outbreaks where the purported source is a cooling tower there is little spatial correlation between the incidence of disease and the alleged source. The unstated assumption is that there is a hidden variable that causes disease seemingly randomly a great distance from the source. This lack of spatial correlation was evident in the South Bronx outbreak where there was no clustering of cases near the purported tower at the Opera House Hotel. What that hidden variable could be is not clear. The following paragraphs describe several well studied outbreaks where, as one would expect, proximity to the source strongly affected the incidence of disease.

In 1999 a spa at a floral trade show in the Netherlands was identified as the source of a large outbreak of Legionnaires' disease. Among exhibitors a close correlation was found between elevated antibodies to *Legionella* and proximity of their booth to the source. The most important visitor-related risk factor was pausing at the whirlpool spa display[7].

Clive Brown et al. investigated a 29-case community outbreak of Legionnaires' disease in 1994 linked to a hospital cooling tower[8]. This investigation showed that the risk of infection decreased by 20% for each 0.1 miles from the hospital and increased by 80% for each visit to the hospital. The paper described an Aerosol Exposure Unit defined as the ratio of time spent near the source and the distance from the source and found a strong correlation between exposure and incidence of disease. The image in Figure 1 taken from this study illustrates the expected distribution of cases of disease from a single aerosol source. The cases are clustered near the source and taper off rapidly at increasing distance.

Proximity was well demonstrated in a 1993 outbreak at a Michigan prison which was traced to a hospital cooling tower. Fourteen (0.6%) of 2253 prisoners who used exercise yards each day within 100 yards of the prison hospital were infected, compared with only two (0.1%) of the 2270 inmates who used yards at least 400 yards from the prison hospital.[9] This equates to roughly a 50% reduction in infection risk in 0.1 miles.

The influence of prevailing wind on aerosol dispersion was addressed by P. Wilmot et al. using geographic information system (GIS) data[10]. They developed plume dispersion models to help locate a potential cooling tower source during outbreak investigations. A plume refers to the moist exhaust air from a cooling tower. The plume will mix with ambient air as it travels away from the tower becoming more and more dilute. If a case occurs outside of the plume dispersion model "the chance that it originated from that cooling tower remains highly unlikely". Figure 2 displays a case where the cooling tower would not be considered a likely source.

The plume is diluted with increasing distance from the tower reducing the concentration of *Legionella* in the air. *Legionella* can live only a relatively short time in the air and contamination at a large distance from the tower is unlikely. A person would need to spend sufficient time near to the tower in order to inhale an infectious dose of bacteria.

Dr. Richard Miller at the University of Louisville has stated:

"Legionnaires' Disease, like all infectious diseases, requires a minimum infectious dose in order to cause disease. While the exact number required for humans varies depending on the susceptibility (i.e. immune status) of the individual, it is likely that the number for most individuals is relatively large. It should be apparent from the ubiquitous nature of this bacterium in the environment, that in order to cause disease, the number of *Legionella* in the water would need to be much higher than that found in most normal aquatic habitats[11]."

The virulence of a particular genetic type of *Legionella* is not a constant and may change during its lifecycle and also may change by exposure to chemicals, heat, or interaction with amoebae. Nevertheless, the ubiquity of *Legionella* in nature implies that everyone has been exposed to at least a low concentration of the bacteria.

In addition to dilution of the aerosol over distance, cooling towers have made dramatic improvements in drift eliminator technology. Drift eliminators are the component of cooling towers that separates recirculating water from exiting air. Over a period of about five years ending around 2000 all major manufacturers of factory-built cooling towers developed low-drift eliminators. These modern drift eliminators reduce aerosol emissions by an order of magnitude from the previous generation of towers. If the water in a cooling tower was contaminated with 1,000 CFU/ml of *Legionella*, a person **standing on top of the tower** and breathing in only tower exhaust for 1 hour would breathe in droplets containing a total of 10 bacteria[12]. As a comparison of transmission pathways between inhalation and aspiration, a person drinking 4 ounces of water from a potable water source contaminated with only 10 CFU/ml would consume over 1,000 bacteria in the few seconds it took to drink the water. These bacteria would be in the mouth and not in the lungs, but the numbers of bacteria that can enter the body are significantly higher with an aspiration route from potable water than inhalation from a modern cooling tower.

As the C. Brown hospital study, the Netherlands flower show study, and the Michigan prison study imply, there should be a dose-response with exposure and incidence of disease. The higher the dose that a particularly susceptible individual receives, the higher will be the likelihood of infection. Also, because of *Legionella's* ubiquitous presence in nature, there should be a threshold dosage below which there is no disease.

The key characteristics of an aerosolized point source exposure to *Legionella* are:

1. The original source of the bacteria is colonization of the potable water supply.
2. While many water-based devices could be contaminated due to an upset in the potable water system, only in one will the bacteria find hospitable growing conditions for amplification and susceptible individuals to infect.
3. The bacteria reproduce in an individual aerosol producing device. This usually requires the water in the equipment to reach temperatures that permit amplification.
4. The bacteria are emitted from a single point.

There is a strong correlation between incidence of infection and proximity of the individual to the aerosol source in both time and space.

While a correlation between proximity to the aerosol source and disease incidence seems fundamental, there are many outbreaks where investigations concluded that this was not the case. This is particularly true of outbreaks attributed to cooling towers. There have been numerous cases, including the July 2015 outbreak in the Bronx, where a cooling tower in the general area was blamed for causing disease without any apparent association of patients with the aerosol source. This lack of spatial correlation between disease incidence and the purported source is an extremely strong indication that the specific cooling tower is not the source of the outbreak.

Potable Water Supply Source

Municipal potable water systems in the United States and European countries have been very effective at reducing, but not eliminating, waterborne diseases. Potable water is sanitary but not sterile. Disinfection is designed to eliminate many pathogens transmitted by the oral-fecal route, such as cholera and typhoid, however many other bacteria that are natural inhabitants of aquatic environments may survive. Most water pipes contain a layer of biofilm. This biofilm may harbor many non-pathogenic bacteria but can also harbor bacteria such as *Legionella*. When a known upset occurs, such as a power outage or water main break which causes loss of system pressure, warnings to boil water before using are sent to the system users. There are an estimated 240,000 water main breaks per year in the United States[13]. Minor upsets such as pressure surges that could disturb biofilms in the pipes may seem unremarkable or go unnoticed yet could release bacteria into the water stream. A study conducted in Wales and northwest England from 2001 to 2002 found a very strong association between self-reported diarrhea and reported low water pressure at the home tap[14]. The investigators hypothesized that most of the reported episodes of pressure loss were due to main breaks in which contamination entered the distribution system. As the infrastructure ages, the frequency of upsets that can potentially cause contamination in the system has increased.

The first incidence in which a municipal water system was found to be the vector for disease transmission occurred during the cholera epidemics in mid-19th century London. Sir John Snow, an English physician, prepared a map of where cholera deaths had occurred. This map[15] clearly showed that most of the deaths were in buildings that received their water from a particular contaminated well that was the source of the disease. However, it took 20 years after Snow generated his map and 8 years after Snow passed away before the correlation between contaminated water and cholera was accepted[16]. The "detection bias" that cholera was caused by airborne "miasma" was too firmly entrenched in the nineteenth century zeitgeist to be easily dislodged. Figure 3 reproduces Sir John Snow's map. Cholera fatalities are indicated by small red circles; public drinking water wells are indicated by larger blue circles. The cases are spread uniformly over the area where the contaminated water was used.

A more recent potable waterborne infection occurred in Denmark in 2007[17]. There an outbreak of gastroenteritis affected a high percentage of residents in one section of the city. Investigation showed massive contamination of a part of the water distribution system, while other parts of the distribution system appeared to be unaffected. The source was eventually identified as backflow of sewage into that portion of the drinking water system. Figure 4 shows the case map for this outbreak with contamination in one subsection of the water supply.

Legionellosis is a waterborne disease. Since the early 1980's, potable water has been known to be a vector for Legionnaires' disease. The best studied cases with a potable water source are hospital acquired infections. A hospital's internal piping system can become contaminated with *Legionella* from the municipal potable water supply. In warm areas of piping, particularly if there is a biofilm on surfaces or sediment in the system, the *Legionella* can multiply and occasionally release large numbers of bacteria into the water[18]. The bacteria may be transmitted to many hospital patients via aspiration of contaminated drinking water or ice chips or, more commonly, via aerosols generated by sinks and showers. Since *Legionella* are not as virulent as cholera this contamination may infect only a few patients per year and appear somewhat sporadically.

The key factors of a potable water outbreak of Legionnaires' disease are:

1. The original source of the bacteria is colonization of the potable water supply.
2. While many buildings could be contaminated due to an upset in the potable water system, only in some buildings will the bacteria find hospitable growing conditions for amplification and susceptible individuals to infect.
3. The bacteria reproduce within several building potable water piping systems to reach infectious levels. This usually requires the water in the system to reach temperatures that permit amplification.
4. The bacteria are emitted at multiple points in multiple buildings throughout the affected portion of the municipal water distribution system.
5. Since the bacteria are emitted from widespread sources there is a seemingly random distribution of cases of disease all within the same municipal water distribution system.

Potable water has also been identified as the source for Legionnaires' disease in non-hospital settings, but again usually with very low infection rates. High risk buildings tend to be tall with complex piping and many residents. If *Legionella* from the municipal water supply colonize sediment and biofilm in a building water system there may be occasional incidents of disease. When multiple cases occur in a single building, the health department will evaluate that building for contamination but rarely investigate other buildings receiving water from the same municipal system. An incident in the municipal potable water supply system that contaminated many buildings over a short period of time could result in an outbreak of disease occurring in the area downstream from the incident over a relatively short period of time.

Epidemiology – Not an Exact Science

Determining the source of a particular outbreak requires gathering and sifting through large amounts of information. Patients are interviewed, commonality between sites visited by patients is evaluated, possible sources are examined, and an attempt is made to match the DNA of infectious bacteria grown from patient isolates to that found in the environment. It is only when all of these fall in line that a source of the disease can be definitively imputed.

As of this writing, there are approximately 2,000 different *Legionella* pneumophila genotypes known worldwide, but only 10% of those are known to be associated with disease in the US[19 20]. A DNA match between environmental and patient isolates is not as determinative of the infection source as one might expect. In a specific geographical region there are usually fewer than several dozen genotypes endemic to the water systems[21]. Since potable water is the ultimate source of the bacteria, many water features in an area can be contaminated with the same genotype of bacteria. In fact particular genetic types of *Legionella* can become endemic to a given water system with the same genetic match appearing in seemingly unrelated environmental sources. Thus the lack of a DNA match can disprove that a particular feature is the source, but a DNA match on its own cannot prove that it is the source.

The difficulty of determining a source was clearly seen in an outbreak in South Dakota in 2007[22]. There had been a dramatic increase in the incidence of Legionnaires' disease over a short period of time. There was little in common with the patients except that they spent time in Rapid City. To the investigators this at first appeared to be a likely cooling tower issue, though there was no clear relationship with time spent near a tower and incidence of disease.

Cooling towers throughout the city were located and sampled. Many had detectable levels of *Legionella* and were required to be disinfected. However, none of the towers *Legionella* were a genetic match to the patients' isolates. The investigators continued to look for other aerosol sources without success as infections were still occurring. Then the investigators noticed that many of the patients had eaten at the same restaurant during their likely infection period. When investigators revisited the restaurant they sampled a small fountain and found both a high level of *Legionella* in the fountain and an exact genetic match to the *Legionella* found in the patients. The fountain was removed and no additional infections occurred.

It was fortunate that none of the cooling towers testing positive for *Legionella* were a genetic match to the particular bacteria that infected patients. Had there been a match, even with little data showing that infected persons spent more time near the towers than the general population, that tower may likely have been declared the source and the fountain would have continued to infect restaurant patrons.

2015 Bronx Outbreaks

Initial Outbreak in South Bronx

During the summer of 2015 a large outbreak of Legionnaires' disease occurred in the South Bronx. The onset dates, 2 to 10 days after the infection dates, were between July 8th and August 3rd. The outbreak was officially declared over on August 20th. During this outbreak 133 individuals were diagnosed with the disease with 16 deaths. The graph in Figure 5 is from the NYC Department of Health[23]. This epidemic curve is characteristic of a common source outbreak where the individuals were exposed to a source of the bacteria over a short period of time. Based on the shape of the curve, this common origin could be an aerosolized source with an upset condition or a municipal water system with an upset condition.

The source of this outbreak was identified by the NYC DOH as a cooling tower on the Opera House Hotel. Note that the particular cooling tower at the Opera House Hotel that was identified as the source of the outbreak had a small 7.5 HP fan and was equipped with modern low-drift eliminators that reduce by an order of magnitude the quantity of drift that the tower emits. The cooling tower was disinfected on August 1st with the last reported case onset on August 3rd. The infection date for all of these cases could have been prior to the cleaning of the cooling tower, though the declining case rate in late July indicates that the outbreak had likely stopped before the tower was disinfected. It is likely that none of the testing and cleaning of cooling towers demanded by the NYC DOH had any effect on ending the initial outbreak.

The cases were distributed fairly uniformly over a large area of the South Bronx. The NYC DOH has provided the map in Figure 6 showing approximately 85 of 133 case locations and the locations of cooling towers.[23] Circles represent cases and triangles cooling towers with the large red triangle at the location of the cooling tower at the Opera House Hotel. Red circles are cases where genetic testing of the *Legionella* was performed. The patient samples and the bacteria found at the Opera House Hotel were of the same genetic type, but as discussed above, genetic typing alone can rule out a potential source but cannot, on its own, definitively establish a source. In fact the particular strain found in the patients and in the Opera House Hotel cooling tower was also found in other features in the area and had caused previous outbreaks in NYC[24]. A particular strain is likely to be present throughout the potable water system, so commonality in **activity** among patients relative to a particular potential source must be established in order to deduce the specific source(s) of infections.

The particular cooling tower located at the Opera House Hotel circulated water at 800 gpm; at full fan power it moves 49,700 CFM; and it is equipped with drift eliminators that reduce the drift to less than 0.001%. The drift rate then is: 0.00001 x 800 gpm x 3785 ml/gal = 30 ml/min. At full fan power this drift results in a concentration of: 30/49700CFM x 1CF/7.48 gal x 1 gal/3.785 liters = 0.00002 ml of drift /liter of exhaust air. If each ml contained 1000 CFU of *Legionella*, then on average there would be 0.02 *Legionella* per liter of undiluted tower exhaust air or in every 50 liters of air there would be a single bacteria. If a typical person has a 500 ml tidal volume and takes 15 breaths per minute, and if they were breathing only undiluted tower exhaust for an hour, they would inhale 0.5 x 15 x 60 = 450 liters of air or only about 10 bacteria. As one moves away from the tower the exhaust air containing the drift becomes more dilute and a person would require much longer time in the diluted exhaust air to inhale a similar number of bacteria.[12]

Recall that proximity has been well established in aerosol point-sourced outbreaks, with reduced infection rates at increasing distance from a source. The circle around the Opera House Hotel in Figure 6 indicates a 0.1 mile radius. This is the area where one would expect the highest cluster of cases, but there is no cluster of cases at or immediately adjacent to the hotel. There is no gradient with radial or, presuming wind, with directional distance. Rather, the cases appear randomly across a broad area, producing a case map with more similarity to the waterborne cholera outbreak. Cooling towers and fountains were sampled as part of the investigation, but potable water was not. City officials repeatedly claimed that "the drinking water is unaffected". This claim was not substantiated with data by NYC because no testing of potable water was performed. In fact it was dramatically disproven in only a few weeks when the cases associated with the Melrose Houses were more fully evaluated.

Outbreak at Melrose Houses

There was a second outbreak of four cases of Legionnaires disease at the Melrose Houses in the South Bronx identified after the initial outbreak. An arrow in Figure 6 indicates the location of the Melrose Houses, less than 0.4 miles from the Opera House Hotel. The first case in the Melrose Houses outbreak occurred in March 2015 and was not investigated at that time. Two more cases occurred during the July outbreak and were originally included in that outbreak, and the latest occurred in late August after the July outbreak was declared over. No potable water sources were investigated by the NYC DOH until four cases were identified at a single location at Melrose Houses. When the potable water at Melrose Houses with over two thousand residents was investigated, *Legionella* were found in the potable water and the potable water was positively identified as the source of infection. Point-of-use water filters were installed on all faucets and showerheads and a copper-silver ionization system was installed in the buildings' potable water piping. In spite of 3 cases occurring in the same facility over a period of only a few months, potable water was not sampled. It was only after the original outbreak was declared over yet an additional case occurred that the potable water was sampled and identified as the source of the infections.

Outbreak at Morris Park

A third outbreak of Legionnaires' disease occurred in the Morris Park neighborhood of the Bronx. Morris Park is about 4 miles from the Opera House Hotel in the East Bronx. There were 13 cases in this outbreak and 1 death. Figure 7 shows the epidemic curve for this outbreak. The onset dates for all but one of the cases included in the outbreak were between September 14th and September 21st with infection occurring 2 to 10 days prior. On August 6 a city wide order had been issued which mandated that:

"Regardless of the outcome of the evaluation required by item (2) above, direct the environmental consultant to carry out a disinfection/treatment sufficient to remove organic material, biofilm, algae and other contaminants and disinfect in a manner sufficient to control for the presence of *Legionella* organisms within 14 days of receipt of this letter"[25]

Due to this city-wide order, all cooling towers in the area had been disinfected by August 20th a few weeks prior to the earliest possible date of infection. If indeed a cooling tower was responsible for the outbreak, then the remediation requirements in the NYC newly enacted laws were ineffective at preventing an outbreak. If potable water or another feature was the source or sources then the newly enacted laws which focus only on cooling towers actually hindered a proper investigation of the outbreak.

In late September, thirty-five cooling towers in the area were tested for *Legionella* and 15 had detectable levels of the bacteria. These 15 towers were disinfected for a second time beginning September 29th, significantly after the outbreak had ended. A press release issued by the NYC DOH on November 20, fully two months after the outbreak had ended, identified a cooling tower as the source[26]. With this outbreak it is unequivocally clear that none of the testing and cleaning of cooling towers demanded by the NYC DOH had any effect on ending the outbreak.

In the large South Bronx outbreak and also in the Morris Park outbreak, infection occurred over a relatively large area in a short time-span. Although the pattern could be due to an upset in the municipal water system simultaneously infecting a large number of buildings, the only sources that were investigated were aerosol point sources such as cooling towers, spas and fountains.

Impact of regulations on public health

Incidence of Disease in the United States and Europe

Legionnaires' disease is a reportable illness in the United States and many European Countries. Records are made available by the CDC[27] in the US and the ECDC[28] in Europe. For 5 European countries these records go back at least to 2003. Figure 8 shows the reported incidence of LD for these countries and the US in illness per 100,000 of population.

There are many factors which can affect the shape of the curves besides actual incidence of disease. Legionnaires' disease is believed to be underreported. The US reported incidence rate has steadily increased over the period shown. The CDC believes that this may be partially due to:

"An increasing population of older persons contributed to the increase in reported legionellosis cases. Other factors that might have contributed include an increasing population of persons at high risk for infection; improved diagnosis and reporting, possibly stimulated by the 2005 CSTE endorsement of more timely and sensitive legionellosis surveillance; and increased use of urine *Legionella* antigen testing[29]".

The graph in Figure 8 shows that there is little difference in the incidence rate of Legionnaires' disease between Western Europe and the United States. This lack of difference exists in spite of burdensome regulation of cooling towers which has been in place in Europe for many years.

Legionella Regulations in France

France provides an interesting study of the effects of cooling tower regulations on the incidence of disease. Guidelines to improve underreporting of the disease were written in 1997 along with introduction of the urinary antigen detection test[30]. In the winter of 2003 to 2004 a large outbreak with 86 confirmed cases and 18 fatalities occurred in Pas-de-Calais, France[31]. An industrial cooling tower was implicated as the source for the contamination. As a result of this outbreak regulations were promulgated for the control of cooling towers. Cooling tower regulations for hospitals had been enacted in 2003 but with the Pas-de-Calais outbreak they were extended to all cooling towers[32].

The 2004 regulations require frequent testing of cooling towers for *Legionella*. The regulations mandate monthly testing for *Legionella* unless 12 consecutive monthly tests are less than 1 CFU/ml then the testing can be reduced to quarterly. If the reading exceeds 100 CFU/ml the tower must be immediately shut down and cleaned. More frequent testing is then required until the system again meets the strict low limits.

The graph in Figure 9 indicates that the incidence rate for LD infection has been hovering around 2 per 100,000 of population for over a decade. After the regulations were issued at the end of 2004, there was an increase in the reported incidence of LD. This could well be due to a heightened awareness of the disease from both the issuing of the regulations and the widely publicized outbreak at Pas-de-Calais. There has been a gradual decline in the reported incidence since 2005, but a dramatic reduction has not been observed since the regulations were implemented. The author believes that these results indicate that the cooling tower regulations had little to no effect on the incidence of sporadic cases of Legionnaires' disease.

Conclusion

There are outbreaks of Legionnaires' disease which have been clearly linked to a sole aerosolized source of bacteria. In these outbreaks, acute proximity and duration were shown to govern exposure and incidence of Legionnaires' disease. However, there are many outbreaks attributed to a cooling tower source which do not adhere to these rules. These outbreaks have case profiles which are more random and cover larger areas. These outbreaks mimic the documented profile of certain potable water outbreaks where a single 'upstream' source contaminates multiple exposure sites.

The source(s) of future Legionnaires' disease outbreaks must be investigated more thoroughly, exploring the possibility of multiple exposure sites **including potable water**, in order to advance our understanding of LD transmission. The traditional epidemiological models that assume causality with a genetic match but with only a tenuous exposure mechanism have resulted in the promulgation of regulations that have not resulted in a significant reduction in the incidence of disease. Increased awareness and the issuing of explicit orders for the care of cooling towers did not prevent the outbreaks from occurring at Melrose Houses or in Morris Park. Strict cooling tower regulations imposed in France after the Pas de Calais outbreak have not resulted in any significant reduction of disease. Is it time we say, perhaps, that it is not always the cooling tower? And what of the other 96% of reported LD cases, those considered sporadic?

A 2006 report issued by the National Academy of Sciences states "Communities should squarely address the problem of *Legionella*, both via changes to the plumbing code and new technologies."[14] The report goes on to call for research projects which specifically address potential problems arising from premise plumbing. Regarding outbreaks the report states, "Environmental assessments of outbreaks should begin to incorporate new insights and allow possible cause-and-effect relationships to be established." This would include a much greater emphasis on dose reconciliation in outbreaks in order to develop basic practical data on dose-response relationships.

Clearly the scientific community recognizes the health risks associated with premise plumbing, or building potable water systems. These potential risks were also well-recognized by the team of experts who contributed to ASHRAE Standard 188 *Legionellosis: Risk Management for Building Water Systems*. The Standard provides minimum Legionellosis risk management requirements for buildings and their associated potable and non-potable water systems. Subsequent to the recent outbreaks, NYC adopted a small subset of the Standard, the portion addressing cooling towers. Adoption of the full Standard, as intended by the expert authors, is necessary in order to have a significant positive effect on public health.

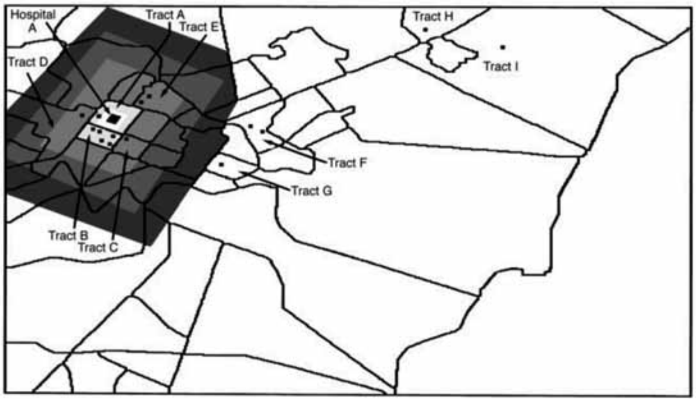

Figure 1 – Case Map from Aerosolized Point-Source

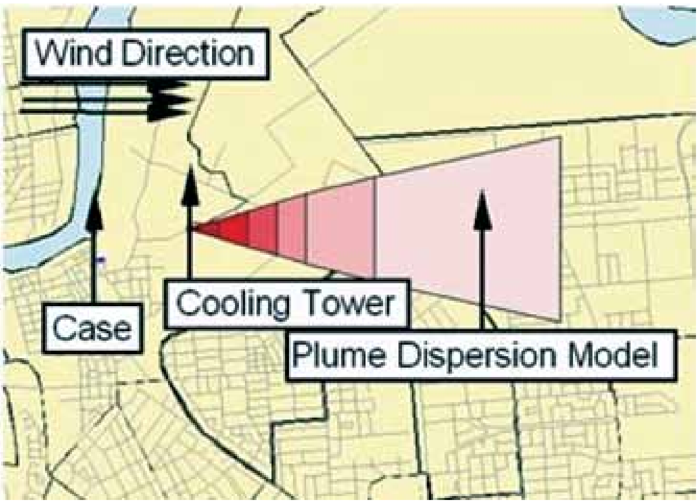

Figure 2 – Case Outside Dispersion Model

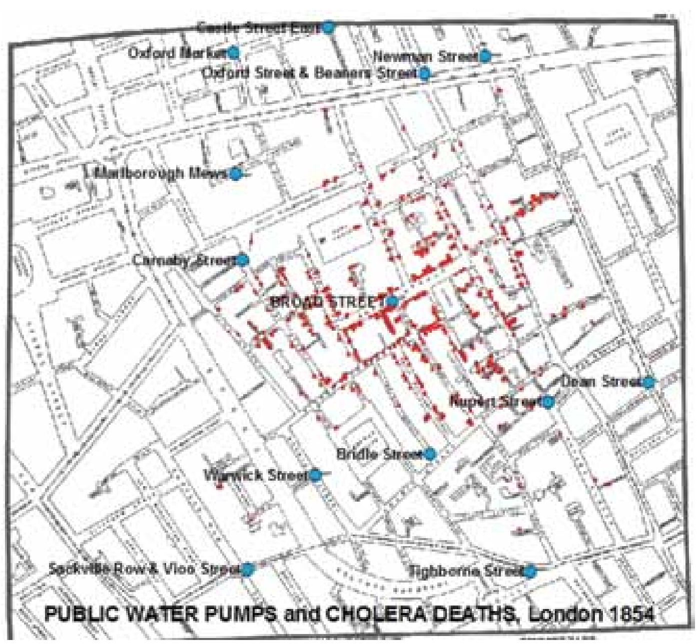

Figure 3 – Cholera Epidemiology London 1854

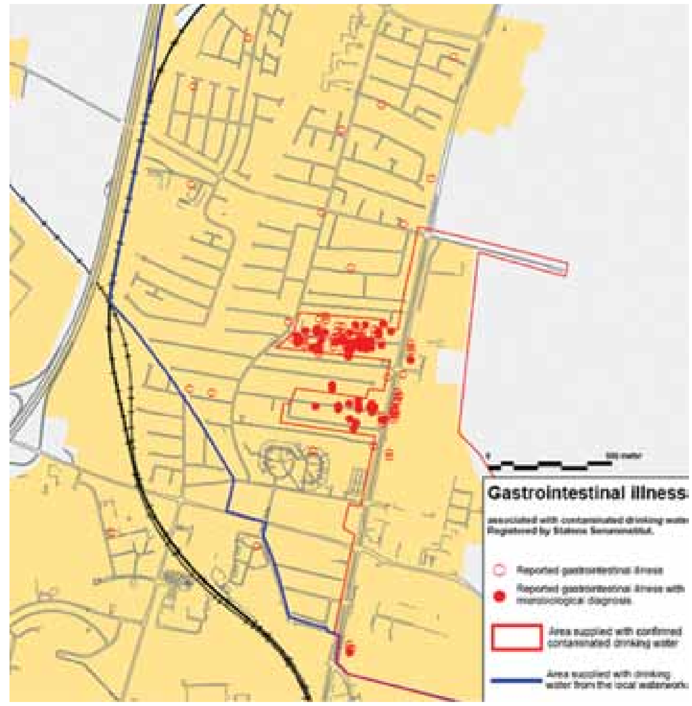

Figure 4 – Gastroenteritis Epidemiology Denmark 2007

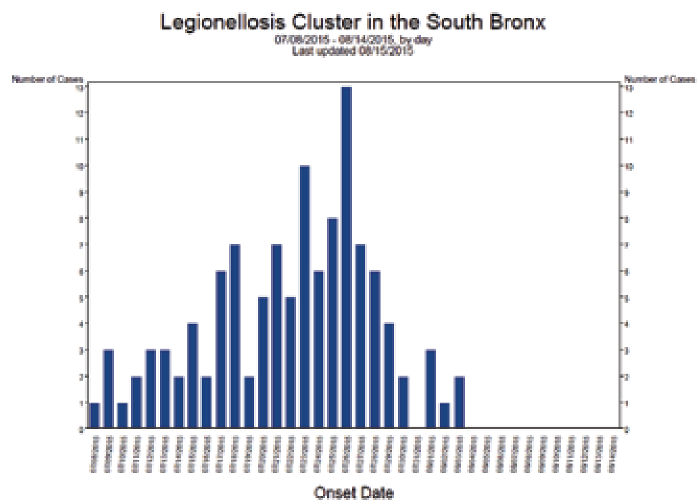

Figure 5 – Epidemic Curve of Initial Outbreak in South Bronx 2015

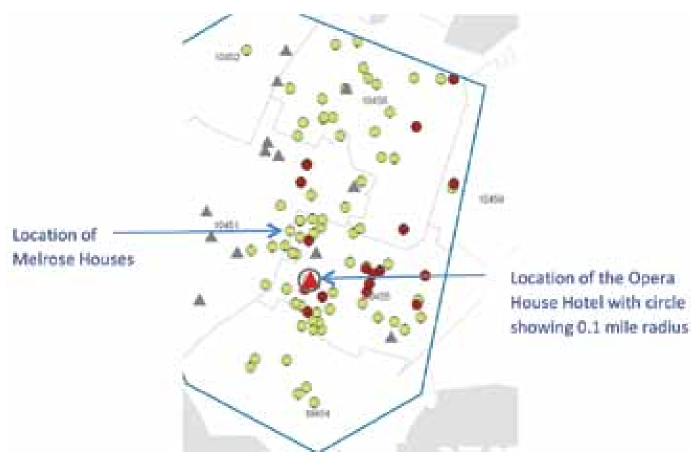

Figure 6 – Map of Cases and Cooling Towers in
South Bronx July 2015 Outbreak

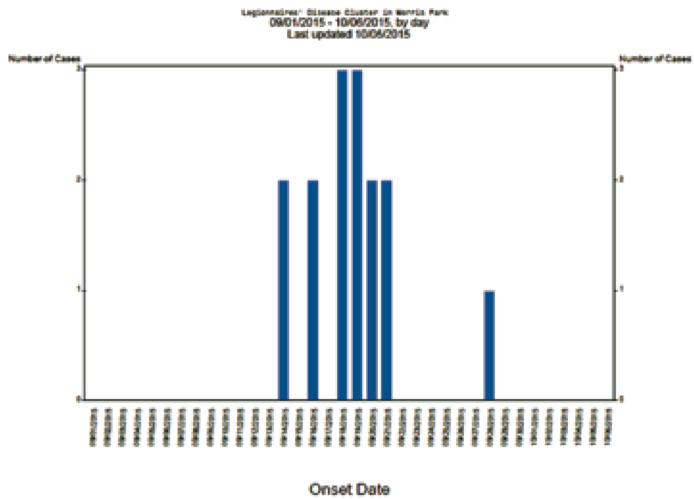

Figure 7 – Epidemic Curve for the Third Outbreak in East Bronx 2015

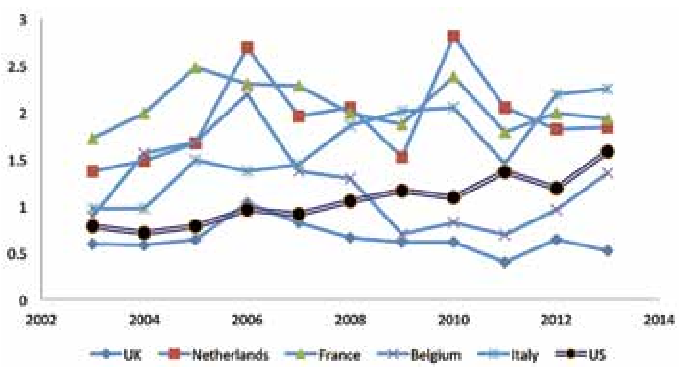

Figure 8 – Incidence of Legionnaires' Disease in the US and Western European Countries

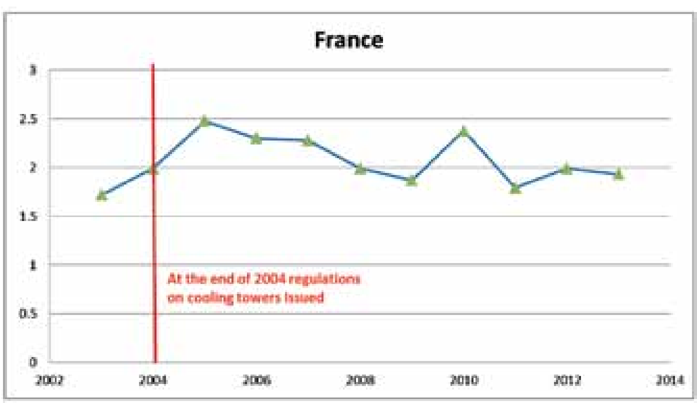

Figure 9 – Incidence of Legionnaires' Disease in France

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