DISEASES ASSOCIATED WITH DRINKING WATER SUPPLIES THAT MEET TREATMENT AND INDICATOR SPECIFICATIONS

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Summary

While outbreaks of waterborne diseases are now relatively rare in most countries where strict regulations exist, there is a recognition that waterborne disease remains at an endemic level that needs to be addressed. Epidemiological studies have suggested that over 30% of all gastrointestinal diseases in some cities could be due to drinking water meeting current standards of quality.

This could be due to the use of contaminated raw water to prepare the drinking water: pathogens with a high level of resistance to treatment and disinfection can occasionally penetrate the barriers provided by the treatment plant. Properly treated water can become re-contaminated in a poorly maintained distribution system, during water mains breaks, cross-connections and a variety of other circumstances. The current indicators of water treatment quality are being challenged and new approaches to drinking water treatment and public health protection are being proposed by the World Health Organization. These should result in further reduction and control of waterborne disease.

1. Introduction

This chapter does not address obvious failures of water treatment: it specifically addresses new findings that are challenging current indicators of treatment efficiency. Essentially, it discusses waterborne disease events associated with drinking water meeting current accepted criteria of water safety. Examples of these events are *Escherichia coli* outbreaks in Canada, USA and UK, as well as large cryptosporidiosis outbreaks in the United Kingdom (UK), United States of America (USA), Australia, Canada and other countries. These events and many others have led to new approaches to setting water quality guidelines.

As we will see, the endemic level of disease due to drinking water consumption has been shown to be quite significant and to contribute to the circulation of enteric pathogens in the exposed populations. The dilemma of balancing microbial and cancer health risk is also a difficult one to resolve, but it should not result in a reduction of treatment efficiency that would compromise the microbiological safety of drinking water. The low risk-level for cancer is usually insignificant when compared to the risk of waterborne infectious disease in absence of adequate water treatment.

Annually, there are still reports worldwide revealing thousands of outbreaks due to bacterial, viral, and parasitic microorganisms associated with the consumption of untreated or improperly treated drinking water. Morbidity and mortality significantly affect children under 5 years of age in countries with poor water quality and reduce their life expectancy in all age groups.

Less apparent health effects of drinking water and their impact on our societies are poorly defined. Public health authorities and water treatment engineers are still attempting to understand the causes that lead to waterborne outbreaks from water supplies that met criteria that had been accepted for safe-drinking water. Most pathogens involved in waterborne outbreaks are well recognized but others are just emerging. Urbanization, aging of water treatment plants, an increasing number of immuno-compromised individuals, and aging populations, are all causes for an increased risk of waterborne infectious diseases.

2. Indicators of water quality and public health

Current indicators of fecal pollution and treatment efficiency have changed very little in the twentieth century. The absence of coliform bacteria (thermotolerant or total), the presence of free residual chlorine and a specified level of turbidity, from 5 NTU to less than 0.3 NTU (Nephelometric Turbidity Unit) at a pH less than 8.0 are probably the most used values to produce drinking water that would be considered low risk.

However, the risks can be quite high even when these criteria are met: several outbreaks of waterborne disease are a testimony to the failure of these indicators

Total or thermotolerant (fecal) coliform bacteria have been the key microorganisms used for the evaluation of water quality and drinking water potability. However, these bacteria are very sensitive to treatment and can be killed with relative ease even at low

chlorine doses: their absence in a drinking water sample does not correlate with the absence of other pathogens such as viruses and protozoan cysts.

Furthermore, sampling strategies for potable water call for only for a minimal number of samples to be taken after treatment. For water treatment plants serving small populations (i.e. less than 1000), samples for bacteriological quality control are tested as infrequently as only once a month: this probably does not provide a sufficient level of protection even if the treatment process is continuously monitored. For larger populations, the usual procedure is to collect one sample per day for bacteriological testing on 100 ml of water before it leaves the treatment works. This is an infinitesimal portion of the volume of water produced (i.e. several thousand cubic meters of water per day).

Identifying a transient contamination of untreated water, or transient failure of treatment, remains quite improbable. It is only through continuous monitoring equipment that one can verify that the treatment is properly applied.

Finally, results from bacteriological testing will normally take 24 to 72 hours and the water would already have been distributed and consumed. It is not surprising that in several outbreaks, dubious water quality was only discovered after the fact.

3. Public health surveillance of waterborne disease

Enteric pathogen infections from viruses, bacteria and parasites result in a wide range of symptoms and diseases. There are over 72 known enteroviruses and infection by these viruses can induce a wide variety of outcomes such as hepatitis (viral type A or E), poliomyelitis, viral meningitis, enteroviral carditis, epidemic myalgia, diabetes and ocular diseases as well as abortions, stillbirth and fetal abnormalities. Bacteria are less involved in properly treated drinking water because almost all are extremely sensitive to treatment and, in particular, disinfection. Viruses and parasites, more resistant to treatment are a challenge. Emerging pathogens and diseases have become a concern for International and National agencies. Examples include *Cryptosporidium*, *Legionella*, *Escherichia coli* O157 (E. coli O157), rotavirus, hepatitis E virus and norovirus (formerly Norwalk virus). Amoebae can cause severe liver or brain infections and contact lens wearers are warned of the dangers of eye infection from these microorganisms. *Legionella* causes severe pneumonia. Some scientists are suggesting the possibility that *Helicobacter pylori*, associated with gastric ulcers, could be transmitted by the water route. Mycobacteria are also being investigated as possible waterborne pathogens. The water-attributable fraction of these infections is relatively unknown.

Once pathogens have been introduced in the water supply and individuals are infected, the public health surveillance system is rarely adequate to identify outbreaks unless they reach significant proportions. Two countries, the USA and the UK, have produced a large amount of data. Most of these data indicate that treatment failures and non-disinfected drinking waters are the most common sources of outbreaks.

Methods for the detection and investigation of waterborne outbreaks have been described, but are still not widely used as resources and funds are critically lacking even in industrialized countries. What surveillance systems and outbreak investigation provide are indications on the causes and sources of contamination and means of preventing future occurrences.

However, given the poor predictive value of current bacterial indicators of treatment efficiency and the very high reliance that most countries still attach to these imperfect parameters, it is not surprising that waterborne disease still occupies a large proportion of the endemic level of enteric diseases, even in the most affluent countries.

4. Epidemiologic studies of endemic waterborne disease

In the absence of evident acute health effects (i.e. outbreaks) and because most public health officials believed that microbial diseases were under control, epidemiological studies have been targeted at long term effects of potentially carcinogenic chemicals. These epidemiological studies do not always provide data that is useful. They are extremely difficult to design and assess, and are often never confirmed due to numerous confounding variables in studies that attempt to analyze lifetime exposure to various factors. Contradictory results are often obtained and exposures from various environmental sources are confounding the issues.

Gastrointestinal symptoms remain the most frequently observed water-related symptoms. Quite often they are endemic in a population (i.e. they are continuously present at low level). This is certainly due to the very apparent nature of these symptoms and an attack rate that reaches over 50% of the exposed population (e.g. Norwalk virus infections). The high incidence of gastrointestinal symptoms has enabled researchers to estimate the waterborne fraction proportion of these infections.

There were several attempts to relate acute symptoms from known pathogens to drinking water quality. Cases of hepatitis A virus could not be correlated with water quality and the risk of waterborne outbreaks. In France, however, acute cases or outbreaks of gastrointestinal illnesses were shown to be associated with poor quality water. In Israel and Namibia, studies on water quality and acute morbidity reported to physicians or nurses were performed in an area with relatively high endemicity of gastrointestinal disease. These studies did not show a relationship between health effects and traditional indicators such as coliforms.

4.1 Canadian studies

Two groundbreaking epidemiological studies conducted in Canada have suggested that a very high proportion of gastrointestinal illnesses could still be attributable to tapwater consumption even when the water met the current water quality guidelines.

The first study was a randomized intervention trial carried out on randomly selected eligible households which were supplied with domestic reverse-osmosis (RO) water filters which eliminated microbial and most chemical contaminants from their tapwater, and randomly selected households which were left with their usual tapwater without

treatment. Gastrointestinal symptoms were recorded by means of a family health diary maintained prospectively by all study families. The estimated annual incidence of gastrointestinal illness was 0.76 among tapwater drinkers as compared with 0.50 among RO-filtered water drinkers.

This is a decrease of 35% of waterborne illnesses by the simple installation of a domestic filtration device. As participants in the RO-filter group were still exposed to tapwater (i.e. about 40% of their water intake was tapwater), it was estimated that about 50% of the illnesses in the area were tapwater-related and preventable.

Attempts were made to correlate the incidence with microbiological data obtained on water samples from the water distribution system, but no significant relationship was found. Attempts were also made to determine the etiology of the observed illnesses. Serums had been collected on four occasions from volunteers and they were tested for antibodies to various pathogens. There was no indication by serology for water-related infections by enteroviruses, hepatitis A virus, rotavirus or Norwalk virus infections.

The second study attempted to re-evaluate the level of waterborne illness and to identify the possible source(s) of pathogens. The same site was studied as it represented an area with a high level of microbial contamination of the river water that it treats, and a high quality of operation of the water treatment plant. Raw water entering the plant was contaminated with parasites, viruses and bacteria at levels found throughout the world in fecally contaminated waters.

The water treatment plant produced water that met or exceeded current Canadian and US regulations for drinking water quality. The rates of highly credible gastrointestinal illnesses (HCGI) were within the expected range for this population at respectively 0.66 episodes/person-year for all subjects and 0.84 episodes/person-year for children 2 to 12 years old. The rate of illness was highest in autumn-winter and lowest in summer. Overall, there were more illnesses among tapwater consumers than among the purified bottled water consumers, suggesting a potential adverse effect originating from the plant or the distribution system.

The rate of gastrointestinal illness among consumers of water obtained directly at the treatment plant was similar to the rate of illness among consumers of purified water, again suggesting a role of the distribution system. Children were consistently more affected than adults and up to 40% of their gastrointestinal illnesses were attributable to water.

The data collected during those two epidemiological studies suggest that there are measurable gastrointestinal health effects associated with tapwater meeting current standards and that contaminants originating from the water treatment plant or the distribution system could be the source of these illnesses. Short-term turbidity breakthrough from individual filters at the water treatment plant might explain the observed health effects. Potential follow-up research should further examine the relationship of turbidity breakthrough to gastrointestinal illnesses, and should investigate the role of the continuously running tap in the occurrence of gastrointestinal illness.

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Biographical Sketch

Professor Pierre Payment obtained his MSc. (Microbiology and Immunology) in 1971 and his PhD. (Microbiology and Immunology) in 1974 from the University of Montreal. Since 1975, he has been a professor at INRS- Institut Armand-Frappier, a research institute and part of the University of Québec. He has been very active both in clinical microbiology, veterinary virology and public health. He is knowledgeable on many aspects of water treatment and microbiology and his current research activities are centered on the health effects of drinking water. As an expert, he has participated in several activities of the USEPA, WHO, Health Canada, OECD, the Walkerton Commission (Ontario, Canada) and the Consultative Scientific Committee of the Joint International Commission on the Great Lakes (Canada).