GOALS OF WATER TREATMENT AND DISINFECTION: REDUCTION IN MORBIDITY AND MORTALITY

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Summary

Mortality and morbidity due to outbreaks of waterborne pathogens have essentially been reduced to rare instances in industrialized countries. Still, waterborne disease remains a constant threat for developing countries and for industrialized countries experiencing catastrophic situations such as earthquake, torrential rains and other natural events. These events can easily upset the delicate balance set in place to protect public health. When properly applied, water treatment processes can easily control waterborne disease transmission and reduce the number of cases of these diseases to an acceptable level. Risk from waterborne pathogens can be controlled through integrated processes such as risk analysis or hazard assessment and control, Data needed for these processes is becoming available and advances in technology now make it possible to react in almost real-time. With the use of these new tools and optimized water treatments, it will be possible to still reduce waterborne diseases and approach as close as is possible a negligible risk from this route.

1. Introduction

Throughout history, all great civilizations attempted to provide to their citizens water with no offensive characteristics (taste, odor, and color) and did not cause overt disease. This is still the basic definition of drinking water and the goal to be attained.

Early treatment was mainly limited to water clarification to make it as transparent as possible, removing visible debris and suspended matter. Sedimentation in clays pots, through cloth filters, through small sand filtration devices provided water free of the larger particles. Partially protected wells or natural springs also provided sources of water that required little or no treatment.

Even if the Greeks and Romans suspected that water was the source of diseases, their main concerns were to provide sufficient fresh water to the urban populations and to eliminate wastewaters from the area. Some Roman aqueducts and sewerage systems are still a tribute to their ingenuity.

However, the clarity of the water and its apparent cleanliness were not sufficient to prevent disease: water was often contaminated and harbored all kinds of disease-causing germs. John Snow, a British physician, elegantly demonstrated at the end of the 19th century that contaminated drinking water was the vehicle of transmission of cholera and set the stage for drinking water quality assessment.

By the end of the 19th century, together with the knowledge of the nature of the microorganisms, came the quest for methods to inactivate and control these germs and the diseases they caused. Various chemical and physical treatments were applied to food and water to lower microbial counts and kill pathogens thereby insuring protection of public health.

With the advancement of science and knowledge, state of the art treatments were developed to reduce to an acceptable level the risks associated with waterborne pathogens. In most industrialized countries, the control of waterborne pathogens and their associated diseases was achieved only during the 20th century and in the 21st century; many still do not have access to safe drinking water.

2. Piped Water networks and Waterborne Disease

By the end-of the 19th century several large urban fires destroyed cities in Europe and America. Firefighting required easy access to water and piped networks were installed in the rebuilt cities. As water quality had to relatively good in order to protect the distribution system from accumulating sediments, sand filtration was introduced to reduce the turbidity and sedimentable particles present in most surface water.

The installation of piped networks and the distribution of water provided instant access to water to the populations in most large urban populations. However, widely distributed water also became a vehicle for the transmission of pathogens to increasingly larger populations with a very high risk of causing enormous outbreaks. As soon as the link between tap water and waterborne disease was recognized, treatment of tap water became an imperative goal in the prevention of enteric diseases.

3. The Diseases

3.1. The Microorganisms

The bacteria, viruses, protozoans and helminths involved in waterborne disease are mostly enteric pathogens associated with fecal material. The symptoms associated with the diseases caused range from unapparent to acute, but most are mild enteric symptoms. The mortality and morbidity associated with waterborne infections is higher in developing countries than in industrialized countries but, apart from helminth infections, all enteric pathogens can be found on Earth everywhere there are men and animals.

Numerous microorganisms can be found in water and some can have significant health effects when ingested. Water must be treated to reduce to acceptable levels any pathogen, chemical or aesthetically objectionable impurities that may be present. The specific goals of water treatment will thus be linked to water quality data available and to the population receiving the treated water.

Pathogenic microorganisms constitute a higher risk than other contaminants (e.g., chemicals, radionuclides). Infection by a pathogen will result in its multiplication in the infected individual with or without disease developing. Since most of these enteric pathogens are easily transmissible (contagious), an infected individual can easily contaminate several others, who in turn, can contaminate others. Thus, the primary infection resulting from the ingestion of contaminated water can easily become the source of a much wider outbreak.

Each pathogen is a particular challenge to water treatment but some are clearly much more resistant to some forms of treatment. The ability of treatment processes to remove microorganisms (pathogens, indicators or surrogate) has been evaluated in bench, pilot and full-scale conditions.

It is generally accepted that cysts of enteric protozoans are the most difficult microorganisms to remove from drinking water as they can survive under normal chlorine concentration for several hours and only a few can induce infection. Viral pathogens are also a challenge, but while some are slightly more resistant to disinfection processes, they are in general inactivated within a few minutes of exposure but only a few can initiate infection. Bacterial pathogens do not generally present a major treatment challenge as they are readily inactivated by disinfectants and human infection requires large doses.

There is currently no surrogate or indicator that can predict the behavior of all pathogens. Thus the safety of drinking water will be the result of source water quality evaluation and monitoring of efficient treatment processes. One of the objectives of water treatment will be to incrementally improve water quality at the same time as other public health measures are taken. Funds are rarely unlimited and choices will have to be made as to where they are the most useful. This will be part of a risk management exercise.

3.2. Prevalence of Gastrointestinal Illnesses

The epidemiology of enteric diseases follows a well-described pattern with its highest prevalence level during winter in the Northern hemisphere. Enteric diseases in a community can only be controlled through a holistic approach that recognizes the numerous sources of contamination and their respective impact. A reduction of waterborne disease should result in a measurable reduction of gastrointestinal illnesses associated with other transmission routes by limiting subsequent person-to-person transmission and environmental contamination. The true health effects of drinking water remain difficult to assess, even grossly, given the numerous routes of exposure to the enteric pathogens under normal daily life (see section 6).

Several epidemiological studies have estimated the prevalence of gastrointestinal illnesses. In the most hygienic conditions the rate was estimated to be 0.5 to 1 episode of illness per year for adults and 3 to 5 episodes for young children. This prevalence of these diseases was probably much higher at the onset of the 20th century, but there are no records of the general morbidity due to enteric diseases. There are however records on cholera and typhoid fevers cases, two highly epidemic diseases that were quite frequent at the time. Both were dramatically reduced during the course of this century and treatment of tap water certainly contributed significantly to this reduction.

3.3. Drinking Water Associated Morbidity and Mortality

The impact waterborne diseases has been well documented in many countries, revealing thousands of outbreaks associated with the consumption of untreated or improperly treated drinking water and due to bacteria, viruses and parasites.

Proper nutrition, access to health care, good sanitation and hygiene, all contribute to a very low level of mortality from waterborne enteric diseases. Mortality from diarrheal diseases can be prevented by aggressive rehydration or antibiotic treatment: this is only accessible in developed countries with an efficient health care system. Under good living conditions, morbidity from enteric pathogens is relatively infrequent and less acute, probably the result of lower exposure to the contaminants. Recent data shows that the losses from poor water sanitation and hygiene account for 7% of all deaths worldwide and 8% in terms of DALY (disability-adjusted-life-year).

The control of the dissemination of enteric diseases by the water route was the result of increasingly efficient water treatments. However, enteric diseases are transmitted through many routes and the exact number of illnesses that are attributable to water remains poorly defined. Morbidity and mortality from the enteric diseases were very high at the end of the 19th century. Improvements in hygiene and sanitation, wastewater disposal, pasteurization of milk, improved preparation and storage of food are all factors that contributed to a general enhancement of public health during the course of the 20th century.

Some form of records of enteric disease outbreaks due to food or water have been kept in most industrialized countries, but this has been systematically done in the United States of America. In other countries, data gathering is often performed very poorly

because of lack of resources to identify the waterborne outbreaks as well as the lack of centralized data gathering official authorities. Several 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. However, they still reflect only a small fraction of the true burden of disease in a population.

Outbreaks are often the result of poorly chosen water sources and water treatment deficiencies. Outbreak investigation provides clues to these deficiencies and helps refine the treatment itself or the surveillance mechanism.

One of goals of water treatment remains to achieve the highest quality at all times through quality assurance and quality control. Enormous efforts are needed to educate all on the importance of water in the dissemination of disease. All levels of society, from consumer to politicians, must be educated to necessity of improving water quality a major step in improving quality of life and health.

Even in industrialized countries, waterborne diseases still constitute a large proportion of the burden of disease. The level of endemic waterborne disease has been estimated to 100 million cases of mild to moderate infections and to socio-economic costs of over 10 billion dollars per year in the United States. Worldwide billions of cases occur annually and millions of deaths are attributable to waterborne diseases.

4. Water Treatment: Control of Pathogens

The goal of water treatment is to reduce the transmission of infectious diseases to an acceptably low level. Guidelines regarding microbial safety aim for the general absence of pathogens and all specify that drinking water should be free of any pathogens that may be detrimental to human health. Guidelines for indicator organisms such as coliforms and *E. coli* provide the basic premise for estimating the quality of drinking water and its treatment. Testing for specific pathogen remains an expensive approach that has not shown to be directly protective of public health. Testing for waterborne pathogens can however provide essential data to estimate the level of treatment required in a risk management approach as will be described later.

The goal of water treatment being to protect public health, microbiological testing which provides only an after-the-fact result provides no direct protection to the population. Consumers have already been exposed to the contaminated water if the treatment has failed. Good source water quality, watershed protection and simple continuously monitored treatments are the best protective measures to verify that the treatment level has been attained. Apart from high cost treatment such as membrane filtration, no single treatment process can be expected to remove all types of contaminants and pathogens found in water. Multiple barriers are an efficient mean of providing additional safety to compensate for occasional inefficiencies in individual treatment steps. The quality of the source water will govern the number and type of barriers to be applied. Water treatment(s) can incorporate, modify, or supplement natural processes in order to provide assurances that the produce drinking water is free from pathogenic organisms or other undesirable substances.

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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).