

## Recognizing waterborne disease and the health effects of water contamination: a review of the challenges facing the medical community in the United States

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### ABSTRACT

Preservation of water quality and prevention of waterborne disease is a complicated task requiring a coordinated effort from many diverse disciplines including physicians, healthcare providers, epidemiologists, microbiologists, academic scientists, science researchers, local and national health authorities, public and environmental health specialists, water engineers and water purveyors. Any successful strategy to ensure water quality and safety in the United States must include the medical community as a valued stakeholder and active participant in this ongoing public health challenge. Unfortunately, the majority of practicing healthcare providers in the US has received limited training in the recognition and evaluation of water-related disease and faces many significant challenges and numerous barriers to diagnosing waterborne disease and the health effects of water pollution in their patients. The purpose of this review is to define the specific challenges facing the medical community with regard to clinical recognition of water-related disease and to provide recommendations for the development of specialized clinical resources and targeted educational outreach programs to assist the medical community in improving their ability to appropriately address water-related disease in their patients.

**Key words** | risk communication, susceptible populations, water pollution, waterborne chemical compounds, waterborne disease, waterborne pathogens

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### INTRODUCTION TO THE PROBLEM OF RECOGNIZING WATERBORNE DISEASE

Contamination of drinking water or recreational waters by infectious pathogens, chemical compounds or radiologic agents has the potential to affect the health of millions of residents in the United States. Preservation of water quality and prevention of water-related disease is a complicated task requiring a coordinated effort from many diverse disciplines including physicians, healthcare providers, epidemiologists, microbiologists, academic scientists, local and national health authorities, public and environmental health specialists, water engineers and water purveyors (Meinhardt 2002). In order for the medical community to participate in this multi-disciplinary effort, they must be educated regarding their important role in recognizing and

preventing waterborne disease and the health effects of water contamination. Any future strategic plan to ensure water quality and safety in the United States must include the medical community as essential stakeholders and important participants in this ongoing public health challenge.

It is important to note that water consumers are frequently unaware of the potential health risks associated with exposure to waterborne contaminants and often consult medical practitioners who are unfamiliar with water contamination from biological, chemical or radiologic hazards and their subsequent impact on human health. Misdiagnosis and underdiagnosis of waterborne disease

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by the medical community is common and may result in morbidity for the general population and, possibly, mortality in vulnerable populations at increased risk of water-related disease (Meinhardt 2002). Water-related disease may result from exposure to waterborne infectious pathogens or from exposure to waterborne chemical and radiologic contaminants. In addition, inadequate diagnosis and under-reporting of cases of waterborne disease by medical practitioners can confound waterborne disease surveillance programs, delay implementation of water treatment procedures, and confuse risk assessment efforts and resource allocation by local, state, and federal governments (Meinhardt 2002). The events of September 11th 2001 add new importance to this public health challenge and emphasize the need for practicing healthcare providers to recognize unusual waterborne disease trends that may result from intentional contamination of water with biological, chemical or radiologic agents (Meinhardt 2003). Medical practitioners throughout the United States must be especially vigilant in light of the fact that they are likely to be the first to observe the early warning signs and changes in illness patterns that may result from intentional acts of water contamination and must understand their critical role in protecting the public's health.

Accurate and timely diagnosis of waterborne disease by the medical community is critically important since the medical, public health, and economic consequences of a waterborne disease outbreak are sobering, particularly if public drinking water is contaminated. A review of two recent examples of waterborne disease outbreaks resulting from accidental contamination of municipal drinking water systems illustrates the serious outcomes for both urban and rural communities. The massive outbreak of waterborne cryptosporidiosis in Milwaukee, Wisconsin in 1993 is an example of how contaminated water distributed through a large municipal water system can lead to a major public health challenge for a metropolitan community (Ford & MacKenzie 2000). An estimated 403,000 Milwaukee residents developed diarrhoea reflecting an attack rate of 52% of the population served by the contaminated municipal water system in 1993 (Mackenzie *et al.* 1994). In addition, more than 4,000 Milwaukee residents were hospitalized during the waterborne outbreak, with cryptosporidiosis listed as the underlying or contributory cause of death in

54 residents following the outbreak (Hoxie *et al.* 1997). It has been estimated that 725,000 productive days were lost as a result of the water contamination event at a cost in excess of \$54 million in lost work time and additional expenses to residents and local government in Milwaukee (HMSO 1995). In 2000, the municipal water supply of the small rural community of Walkerton, Ontario was contaminated with *E. coli* O157:H7 resulting in 2,300 symptomatic residents and seven deaths attributed to the waterborne disease outbreak (Meinhardt 2002). More than \$11 million was required to re-construct the rural community municipal water system and install temporary filtration after the *E. coli* O157:H7 contamination event. In 2000, the estimated total cost of the Walkerton, Ontario waterborne disease outbreak and municipal water contamination event had already reached \$155 million (Meinhardt 2002).

Preservation of water quality and prevention of waterborne disease is a complicated task requiring a coordinated effort from many diverse disciplines including practicing healthcare providers in addition to local and national public health authorities, water utility practitioners, water quality and regulatory specialists, environmental scientists and engineers, and basic science researchers. Any successful strategy to ensure drinking water quality and safety in the United States must include the medical community as a valued stakeholder and active participant in this ongoing public health challenge. In order for the medical community to participate in this multi-disciplinary effort and work in collaboration with new environmental health partners, they must be educated regarding their important role in recognizing and preventing waterborne disease and the health effects of water contamination. Unfortunately, the majority of practicing healthcare providers in the United States have received limited formalized training in the recognition and management of waterborne disease or the short and long-term health effects of water pollution during their medical education or subsequent years in active clinical practice. Therefore, the purpose of this review is to define the specific challenges facing the medical community with regard to recognizing and managing water-related disease, describe the unique barriers to improving the recognition of water-related disease by healthcare practitioners, and provide recommendations for effective educational outreach and provision of clinical resources to

assist the medical community improve their ability to appropriately address water-related disease in their patients and local communities.

## SPECIFIC CHALLENGES FACING THE MEDICAL COMMUNITY

### Clinical and diagnostic challenges to recognizing waterborne disease

Recognizing and treating waterborne disease and the health effects of acute and chronic exposure to water pollution is a diagnostic dilemma for the majority of practicing physicians in the United States. Healthcare practitioners face many challenges when attempting to accurately diagnose and appropriately manage and treat waterborne disease and the sequelae of acute and chronic exposure to waterborne contaminants. These significant challenges include but are not limited to the following scenarios:

- Many of the signs and symptoms of waterborne disease and the health effects of water pollution are non-specific and often mimic more common medical conditions and disorders (Meinhardt 2002).
- Patients may not be aware of their previous waterborne exposure to biological, chemical or radiologic agents and obtaining an accurate exposure history from the patient is often very difficult (Meinhardt 2002).
- Public drinking water may represent only one source of waterborne exposure and other exposure scenarios must also be investigated by the healthcare provider during the exposure history such as exposure to contaminated recreational waters, swimming pools and water parks, medical or dental devices, and commercial bottled water (Meinhardt 2002).
- Co-infections with multiple waterborne pathogens or exposure to a mixture of chemical agents are common scenarios in many patients exposed to waterborne contaminants complicating an accurate diagnosis (Meinhardt 2002; Meinhardt *et al.* 1996).
- Many of the infectious pathogens and chemical contaminants found in the water environment are not unique to water and may exhibit multiple routes of exposure and result from other sources of contamination

in the patient's environment such as food, soil, and air (Meinhardt *et al.* 1996; Brooks *et al.* 1995).

- Waterborne exposure events in a healthy patient population may present as benign symptoms or self-limited illness while the same waterborne exposure events in a vulnerable patient population may result in significant morbidity including chronic and life-threatening disease and, in some cases, death (Meinhardt *et al.* 1996).

When assessing the impact of waterborne disease in the general population, the clinical and diagnostic challenges faced by the medical community are often complex and difficult. However, it is even more challenging to evaluate and manage certain individuals at greater risk for morbidity and mortality from exposure to waterborne pathogens and contaminants (Gerba *et al.* 1996). Susceptible or vulnerable subpopulations may experience significant medical sequelae from water-related disease at lower levels of exposure to waterborne contaminants than the general population.

### Special challenges and precautions for high-risk susceptible populations

The medical community faces several additional challenges when evaluating and managing water-related disease in vulnerable or sensitive populations who may develop water-related disease at lower levels of exposure to waterborne contaminants than the general healthy population (EPA 2000; Meinhardt 2002). The segment of the national population currently identified as at increased risk for developing disease from lower levels of exposure to waterborne microbial or chemical contaminants represents 20% of the US population and includes both immunosuppressed and immunocompromised patients (EPA 2000). This percentage is expected to grow as life-spans increase and immunocompromised individuals survive longer (Gerba *et al.* 1996). In addition, children and neonates may be at greater risk resulting from biological factors such as higher ratios of skin surface to body mass resulting in a proportionally greater body burden of water contaminants than in adults (Olin 1998; Meinhardt 2002). These factors reinforce the fact that healthcare providers are faced with addressing the special needs of susceptible or high-risk populations that may develop severe and fatal systemic

disease from the same waterborne exposure that may present as an asymptomatic or mild illness in the general population (ILSI 1996; Meinhardt 2002).

Therefore, healthcare practitioners are challenged with defining which of their patients may be considered a member of a susceptible or sensitive subpopulation in order to determine whether their specific risk profile for water-related disease warrants special health precautions. Patients who may be categorized in these sensitive subgroups (Figure 1) warrant special clinical attention and risk reduction education by their healthcare providers in order to prevent the adverse health outcomes which may result from their increased risk of developing water-related diseases (HMSO 1995; Gerba *et al.* 1996; EPA 1999; EPA 2000; Anon 2000; Meinhardt 2002).

Another important clinical challenge which healthcare practitioners face when determining susceptibility to waterborne contaminants is the fact that an individual patient's susceptibility does not remain constant or fixed in time (Reiser 1995; Meinhardt 2002). Even members of the general population not specifically designated as at high-risk or vulnerable subgroup may at various times in their life become more susceptible to waterborne contaminant exposure. During an individual patient's lifetime, their susceptibility changes with age from a highly susceptible developing fetus to a low risk status as a healthy adult to increased susceptibility as an elderly patient with chronic disease. Intermittent illnesses or accidental trauma may require a re-evaluation by the healthcare practitioner

which shifts the susceptibility status of a healthy low-risk individual to one of a susceptible patient requiring special consideration and protection from the adverse health effects of waterborne contaminant exposure (Reiser 1995; Meinhardt 2002).

### Unique challenges including health risk communication and patient education

Although the medical community may be unfamiliar with how to recognize and manage waterborne diseases and the health effects of water pollution, several surveys indicate that the general public trusts healthcare providers more than other sources to provide them with accurate information regarding environmental health risks including information addressing waterborne disease. Healthcare providers are increasingly faced with complex questions from their patients regarding the health risks associated with environmental exposure to both infectious and chemical contaminants in water. Two recent surveys concluded that healthcare practitioners have an opportunity to play a central role in providing information to their patients regarding water contaminant exposure and risk reduction behavior. One survey indicated that healthcare providers are among the most trusted sources of information for the general public regarding drinking water quality and safety in the US (Anon 1999). Another survey revealed that information regarding drinking water safety and risk reduction education was more likely to result in

Selected susceptible populations at increased risk for water-related disease <sup>a</sup>
Pregnant women and developing fetuses
Neonates, infants and children
Geriatric patients including nursing home residents
Immunosuppressed individuals including HIV and AIDS patients
Patients undergoing immunosuppressive therapy including organ transplant patients
Patients treated with chemotherapeutic agents including cancer patients
Patients with pre-existing clinical disorders or chronic diseases resulting in impairment of the renal, hepatic or immunologic system

**Figure 1** | Susceptible populations of patients who warrant special attention and risk reduction education by healthcare providers. <sup>a</sup>Modified from *Recognizing Waterborne Disease and the Health Effects of Water Pollution: Physician On-line Reference Guide* accessible at [www.WaterHealthConnection.org](http://www.WaterHealthConnection.org) (Meinhardt 2002).

preventive behaviours by patients, if the information was provided by a healthcare provider rather than another source (Griffin & Dunwoody 2000).

Therefore, medical practitioners are in a unique position to act as health risk communicators and provide scientifically sound information to their patients regarding their specific risk for developing water-related disease. However, several significant challenges face the healthcare provider when attempting to provide effective patient education regarding the risk of exposure to waterborne contaminants and the possibility of developing water-related disease:

- There is often a mismatch between what the patient believes to be an important environmental health concern and what the facts support. Therefore, the medical practitioner is challenged with communicating highly technical scientific information about risk in a fashion that is understandable and credible to the patient (Cullen *et al.* 1995; Meinhardt 2002).
- Skillful risk communication is necessary since it is not always possible to establish with certainty that the patient's disease has been caused by a specific waterborne contaminant exposure. The healthcare provider is often required to communicate information about the probability that the patient's disease may have been caused by an environmental contaminant exposure (Cullen *et al.* 1995; Meinhardt 2002).
- Many patients (the "worried well") may believe that a minor waterborne contaminant exposure may result in immediate risk of serious illness. At the other end of the spectrum, many "at risk" patients seriously underestimate their risk of developing water-related disease and disregard the need to act cautiously (Cullen *et al.* 1995; Meinhardt 2002).

## BARRIERS TO IMPROVED CLINICAL DIAGNOSIS OF WATER-RELATED DISEASE

### Clinical constraints and time restrictions of practicing clinicians

The paucity of direct educational outreach programs and resources in the United States which provide practicing healthcare providers with clinically relevant information addressing the diagnosis, evaluation, and management of

waterborne disease is a significant barrier to improved clinical recognition of water-related disease by the medical community (Meinhardt 2002). Several additional barriers exacerbate the problem of improved clinical diagnosis, management, and prevention of waterborne disease by the medical community including lack of immediate access to targeted clinical information and severe time constraints during a patient care office visit. A report from the National Academy of Sciences Institute of Medicine concluded that two of the principal concerns of primary care physicians faced with evaluating environmental disease (including water-related disease) in their patients were: (1) the paucity of environmental health resources available to primary care practitioners and (2) the lack of a "single-access point" for information necessary to appropriately evaluate environmental exposure and resulting clinical disease (Sublet 1995). In addition to these barriers, healthcare practitioners are also confronted with a massive volume of new medical information on a daily basis and often evaluate 20–30 patients each day during their typical clinical practice routine. In light of the severe time restraints experienced by many busy clinicians, incorporating any new clinical information into their practice routine (particularly information addressing waterborne disease and the health effects of water pollution) is a very difficult challenge (Richardson & Mulrow 2001; Meinhardt 2002).

### New diagnostic challenges including emerging pathogens, water pollution, and water terrorism

An additional barrier to improved diagnosis, and management and prevention of waterborne disease and the health effects of water contamination, by the medical community, is the ongoing challenge of newly emerging waterborne pathogens, potential degradation of water resources with a diverse array of environmental pollutants, and the current threat of intentional contamination of water or water terrorism (Meinhardt 2002; Meinhardt 2003). Healthcare practitioners will face even more complex and challenging diagnostic dilemmas when evaluating their patients for possible exposure to waterborne disease or the health effects of water pollution and contamination in the future. New diagnostic challenges which create ongoing barriers to improved clinical diagnosis, management and prevention of



waterborne disease by medical practitioners include but are not limited to:

- Emerging infectious diseases continue to challenge the medical community's clinical knowledge base with many new infectious diseases identified over the past 10 years and the incidence of these diseases increasing yearly (Strausbaugh 1997). Several of these new infectious pathogens may be transmitted to humans through the waterborne route of exposure (Meinhardt 2002).
- An estimated 64,000 chemicals are in use commercially in the United States with approximately 700 new chemical agents synthesized each year challenging the nation's ability to control and prevent environment pollution of air, soil, and water by these industrial compounds. The medical community will continue to be faced with evaluating patients who may have been exposed to potentially hazardous chemical agents which have contaminated their drinking water from either the production or industrial use of these chemical compounds (Meinhardt 2002). Unfortunately, approximately 500 of these chemical agents have been evaluated for carcinogenic potential with the vast majority never being subjected to thorough toxicity testing for human health effects (Philip 1995).
- Although efforts to protect the security of the nation's 168,000 public drinking water systems remain resolute, intentional contamination of water in the United States is a possibility as part of an organized effort to disrupt the nation's critical public infrastructure. The Centers for Disease Control and Prevention (CDC) recently called upon the medical community to remain vigilant, as they will probably be the first to observe and report unusual disease trends allowing for early detection and subsequent control of biological, chemical or radiological assaults on the nation's infrastructure including intentional contamination of water (Meinhardt 2002; Meinhardt 2003).

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### RECOMMENDATIONS FOR IMPROVED CLINICAL DIAGNOSIS OF WATER-RELATED DISEASE BY THE MEDICAL COMMUNITY

Accurate and timely diagnosis of water-related disease by the medical community is a critical element to any

successful strategy to protect water quality and the public's health. This review has detailed the significant challenges and numerous barriers which the medical community faces when attempting to address the diagnosis, evaluation, and management of waterborne disease and the health effects of water pollution. In order for healthcare providers to improve their clinical knowledge of water-related disease and to enhance their understanding of water quality issues in their community, they must be provided with targeted clinical resources and specialized information which is available to them during routine clinical activities (Meinhardt 2002). Clinically relevant information and specialized educational resources must be developed for the medical community as well as educational outreach programs offering specialized training in waterborne disease recognition (Meinhardt 2002). These educational resources and training programs must incorporate three major areas of increasing importance to protecting public health and water safety.

### Basic understanding of water protection strategies and waterborne disease trends

In order for healthcare providers to accurately diagnose water-related disease and provide appropriate risk communication information to their patients regarding water quality and safety, they must acquire a basic working knowledge of water protection strategies and understand the vulnerabilities with respect to contamination of water delivery systems (Meinhardt 2002). Educational outreach programs and targeted clinical resources should also include a discussion of waterborne disease trends and outbreaks by water source, major causes of water pollution, and various mechanisms of exposure to water contaminants which their patients may experience. This understanding is crucial in order for healthcare providers: (1) to counsel their patients more appropriately regarding their personal risk profile and their potential to develop water-related disease and (2) to complete more comprehensive and accurate exposure histories when patients present with symptomatology consistent with waterborne disease (EPA 1999; Meinhardt 2002).

### Evaluation and management of water-related disease resulting from biological, chemical, and radiologic contaminants

A synopsis of the sources of exposure, routes of transmission, symptomatology, and clinical management guidelines for the most common infectious waterborne pathogens encountered in the US must be included in any educational outreach effort targeting the medical community. An overview of major waterborne chemical and radiologic pollutants and their associated health effects should be incorporated in resources developed for healthcare providers as well. In addition, a review of the appropriate use of diagnostic laboratory testing and the need for standardization of laboratory detection and analysis in local community medical centers is imperative. The mechanisms for reporting suspected waterborne disease and water contamination cases to public health authorities and the role which local water utility practitioners play in water protection efforts such as ongoing monitoring of infectious pathogens and chemical agents in water reserves is also an important element.

### Evaluation and management of water-related disease in susceptible populations and patient risk communication

Another important element of any educational resource developed for the medical community must include an examination of the special health needs of sensitive populations at greatest risk for morbidity and mortality from exposure to waterborne contaminants. These educational resources must incorporate presentation of state-of-the-art health advisory guidelines and medical protocols for management of high risk patients. Identification of "at risk" groups with focused emphasis on immunosuppressed and immunocompromised patients, pregnant women and developing fetuses, and infants and children must be included as a key element in specialized material prepared for medical practitioners. Specific information addressing the relative risk associated with waterborne contaminants for the general population in comparison to the health risk of vulnerable populations must also be emphasized. A review of risk communication tools and patient education materials and techniques addressing waterborne disease and the health effects of water pollution which are

appropriate for use in a clinical setting should also be prioritized for development.

### CONCLUSIONS

Preventing waterborne disease and the health effects of water contamination is vital to our nation's public health due to the fact that access to safe drinking water is a required cornerstone of public health. Modernized sanitation methods and access to potable water have increased the lifespan and improved the general health of US citizens more than any other advancement in the field of medicine (Last 1998). As this review has made apparent, there are numerous barriers to improving the clinical diagnosis of waterborne disease and the health effects of water contamination by the medical community. In order for the medical community to overcome these significant challenges, they must be provided with the essential tools necessary to diagnose, manage, and prevent water-related disease if the health of their individual patients as well as the public health of the nation is to be protected.

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