

# 12

## Approaches to risk management in priority setting

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### 12.1 INTRODUCTION

Traditionally, the role of the public health community is in prevention rather than treatment of disease. Increasingly, it has been recognized that the HACCP approach used extensively in the food industry (Doores 1999), may also be appropriate for prevention and control of waterborne disease (Deere *et al.* 2001). Water source protection, water treatment, disinfection and distribution all provide critical control points for applying the HACCP approach. Critical levels can be established through dose-response modelling and monitoring approaches developed for specific pathogens or surrogate markers of microbial contamination. The field of molecular epidemiology

has begun to provide the tools to monitor for the presence of pathogens that have yet to be cultured (Rose & Grimes 2001).

However, in order to effectively use the HACCP approach for protection of public health from a specific waterborne pathogen, fundamental criteria need to be met. These include the following: 1) the pathogen needs to be established as a hazard to human health by the specific exposure path of interest; 2) dose-response studies need to be conducted to establish critical control levels; 3) effective monitoring techniques need to be available to evaluate those control levels; and 4) effective treatment must be available at each critical control point. To date, it is unclear whether this approach could be effective for control of diseases caused by environmental mycobacteria.

## 12.2 PUBLIC HEALTH RESPONSE

To date, the public health response to the environmental mycobacteria has been directed at disease management and not at prevention. This fact is not surprising, as current epidemiological data has failed to provide a convincing link between exposure to waterborne mycobacteria and disease. As a result, prevention of mycobacterial growth within water distribution systems and domestic hot water systems has received little attention. Most outbreaks that have been epidemiologically-linked to water have been small in scale, and none are directly linked to ingestion of tap water.

Although it is certainly true that data is as yet insufficient to provide a link between ingestion of tap water and mycobacterial disease, there is now considerable evidence that environmental mycobacteria present a health hazard through exposure of abraded skin to swimming pools, spas, hot tubs, footbaths, and aquaria (refer to Chapter 8). These exposures generally lead to skin and soft tissue infections (Collins *et al.* 1984). Inhalation of contaminated aerosols has also been linked to illnesses that range from hypersensitivity pneumonitis to pneumonia (Embril *et al.* 1997; Shelton *et al.* 1999; see also Chapter 9). The hospital environment also poses specific routes of exposure to environmental mycobacteria. Contaminated tap and deionized water used in bronchoscopy procedures has been linked to mycobacterial infections (see Chapter 10) that have been readily controlled by installation of microbiological filters in the water source (Stine *et al.* 1987; Graham *et al.* 1988). In the case of recreational and hospital exposures to mycobacteria-contaminated water, the management response has been relatively straightforward. For control of recreational exposures, rigorous adherence to appropriate disinfection treatment, including superheating of water and education to minimize abrasions, is recommended (WHO 2000). For hospital water, microbiological filtration at tap water sites has been relatively effective.

It is instructive to examine the public health response to *Legionella pneumophila*, an opportunistic pathogen with similar etiology. *L. pneumophila* is similar in many aspects to mycobacterial species in that it is truly an environmental pathogen, it is relatively resistant to water treatment and disinfection, it survives intracellularly within

amoebae, it survives within biofilms, it is prevalent within hot water systems and can be transmitted by the aerosol route, through direct ingestion or through skin abrasion (Kramer & Ford 1994). Table 12.1 lists the similarities and differences between these environmental pathogens.

**Table 12.1** Similarities and differences between *Legionella* and *Mycobacterium* species.

	<i>Legionella</i> spp.	<i>Mycobacterium</i> spp.
Present in source waters	Yes	Yes
Resistant to treatment	Somewhat	Very
Survives intracellularly	Yes	Yes
Intracellular survival affects virulence	Yes	Yes
High mortality risk	Legionellosis, Yes (15%) Pontiac Fever, No	No (accept for HIV/AIDS)
Biofilm survival	Yes	Yes
Aerosol survival	Yes	Yes
Growth range	20-45 °C	Similar, depending on species
Maximum temperature	< 60 °C	Probably similar, depending on species <sup>1</sup>

<sup>1</sup>*M. tuberculosis* can survive at 60°C for 10 minutes, environmental mycobacteria may be even hardier

The public health response to *L. pneumophila* has been mixed, and its effectiveness is debatable. This is in part due to the relatively low rate at which legionellosis is diagnosed. It is thought today that a large percentage of hospital-acquired pneumonias are due to *L. pneumophila*. The CDC estimates that between 8000 and 18 000 people get Legionnaires disease each year in the United States, with mortality ranging from 5 to 30%. *Legionella* is one of the very few named organisms on EPA's National Primary Drinking Water Regulations List, with a Maximum Contaminant Level Goal of zero, and a Maximum Contaminant Level currently defined as a treatment technique that can effectively remove/inactivate *Giardia* and viruses. The rationale for including legionella on this list is relatively clear. Legionellosis has a high mortality risk and the routes of exposure are relatively clearly defined. It can be isolated from source and drinking-water, and outbreaks have been directly linked to cooling towers, whirlpools and showers. As a consequence, there are many resources available to public health practitioners seeking guidelines for minimization of health risks from *Legionella*. For example, Australia has published "Health (Legionella) Regulations 2001" that are specifically designed to:

- prescribe procedures for the maintenance and testing of cooling tower systems and warm water systems;
- require owners and people who have the management or control of cooling tower systems and warm water systems to keep records on the maintenance

and testing of those systems and to make those records available for inspection by an authorized officer on request;

- enable the Secretary to the Department of Human Services to—
  - a) substitute different procedures in certain circumstances;
  - b) require additional procedures to be undertaken when a system is suspected or implicated in the spread of the prescribed infectious disease, legionellosis.

Other countries have published their own guidelines and codes of practice; for example, the Health and Safety Commission of the United Kingdom has published an approved code of practice and guidance for Legionnaires disease (HSC 2001).

A number of resources are available for hospitals. In the United States, there are numerous web-based resources to allow hospitals to develop management plans for *Legionella*. In fact, the Joint Commission on Accreditation of Healthcare Organizations specifically includes minimization of risks from “organizational-acquired illness” in regulation JCAHO EC 1.7. This standard also requires that health care facilities are responsible for “management of pathogenic biological agents in cooling towers, domestic hot water, and other aerosolizing water systems.” In the industrial setting, the OSHA provide links to information on Recognition, Evaluation, Control and Compliance. This includes information on cooling towers, heating, ventilation and air-conditioning systems, hospital control and specific industrial issues that include exposure of workers to *Legionella* in the plastic injection moulding industry and workers in contact with metal-working fluids (<http://www.osha.gov/SLTC/legionnairesdisease/index.html>).

The argument has apparently not yet been made for mycobacterial species, although there is clear evidence for outbreaks of disease related to many of the same exposure paths. Indeed, control for the mycobacteria may in part be achieved through control for *Legionella*, and it is certainly likely that utility management plans in hospitals that are designed to reduce risk from *Legionella* will reduce risks from the pathogenic mycobacteria in drinking and shower water, hydrotherapy, spa pools, etc. However, it should also be recognized that the mycobacteria are probably more resistant to disinfectants than *Legionella*.

## 12.3 MANAGEMENT OPTIONS

### 12.3.1 Drinking/bathing water

Management options for municipal water used for household uses such as drinking and bathing should be aimed at a level that minimizes risk to the most susceptible populations. In some countries, for example, pregnant women may bathe for extended periods (hours), particularly where hot water supply is centrally controlled and essentially free (Egorov, personal communication). The major problem is the inability

to quantify risk. A number of studies have shown colonization of water systems with environmental mycobacteria, including MAC (Glover *et al.* 1994; Montecalvo *et al.* 1994; von Reyn *et al.* 1994) and *M. gordonae* (Le Dantec *et al.* 2002). However, the epidemiological link between presence of MAC in potable water and disease has not been effectively made. In fact, major studies designed to address sources of disseminated MAC infection in people with HIV/AIDS have failed to find an association with home water, including home showering (Horsburgh *et al.* 1994; von Reyn *et al.* 2002). The more recent publication concludes that “MAC infection results from diverse and likely undetectable environmental and nosocomial exposures.”

The undeniable presence of environmental mycobacteria in municipal water presents a number of exposure routes within the home, including drinking, bathing, food preparation and even toilet flushing (Arbeit, personal communication). However, without the epidemiological link with disease, the role of public health and water management is unclear. Water treatment itself is likely to be ineffective due to the high level of resistance of mycobacteria to disinfection (Le Dantec *et al.* 2002) and other environmental stressors such as starvation, desiccation and temperature extremes (Archuleta *et al.* 2002). The ability of mycobacteria to survive intracellularly within amoebae (Cirillo *et al.* 1997), and within biofilms (Hall-Stoodley *et al.* 1999), would additionally suggest that current treatment technologies are unlikely to remove mycobacteria from drinking-water, or prevent persistent colonization within the distribution system (see Chapter 11).

What then are the alternatives for water management? In the United States, MAC is listed on the CCL developed in 1998 to direct future regulatory efforts of the USEPA. It was not, however, included on the unregulated contaminant monitoring rule of 1999, presumably because the epidemiological link with disease had not been made. It remains to be seen as to whether MAC will remain on the CCL for 2003, or be considered in the second round of unregulated contaminant monitoring rule, scheduled for 2004. However, without a stronger public health connection, it will be difficult to justify its further regulation. The similarity between the etiology of environmental mycobacterial disease and the etiology of legionellosis is remarkable. *L. pneumophila* is a regulated contaminant in drinking-water, yet most outbreaks of legionellosis are linked to recreational, industrial and institutional exposures. The major difference between mycobacterial infections and legionellosis is the high mortality rates associated with the latter disease, the well-documented survival of *Legionella* in warm/hot water systems, and the now extensive number of epidemiological studies that link specific outbreaks to cooling tower aerosols.

As with *L. pneumophila*, the source of many environmental mycobacteria is likely to be potable water and exposure may predominantly occur through inhalation of contaminated aerosols or aspiration of drinking-water. Until a stronger epidemiological link is made, no definitive regulations are likely to be acceptable, or

even possible to implement. For the most susceptible populations, recommending point-of-use microbiological filtration provides the only management option to date.

### 12.3.2 Recreational water

Management options for recreational waters are relatively straightforward. In general, most outbreaks of mycobacterial infections (as with *Legionella*) can be related to overcrowding in the facility, insufficient disinfection, poor filter and piping maintenance. Swimming pools and hot tubs can be periodically shock-treated with much higher levels of disinfectants than can be used for a potable water system. A number of guides for disease prevention are available on-line and essentially provide comprehensive management instructions for both private and public swimming pools, hot tubs and spas (e.g. Freije 2000). Careful maintenance and cleaning schedules are critical, as piping and filter material can provide an ideal environment for microbial colonization. It is also suggested that bathers should be encouraged to avoid any behaviour that could result in scrapes and scratches (WHO 2000). It is probably also appropriate to caution immunocompromised individuals about their elevated health risks from recreational water exposure to mycobacteria (and other pathogens) (WHO 2000). Superheating water to 70 °C on a daily basis (Embil *et al.* 1997) can also be an effective mechanism for reducing environmental mycobacteria (as well as *Legionella*).

### 12.3.3 Industrial exposure

The industrial environment in the United States is regulated by OSHA. OSHA provides a wide range of resources for minimizing risks of worker exposure to *Legionella* (e.g. OSHA 1999). Environmental mycobacteria present similar problems, but may be harder to control in the work environment due to their greater resistance to disinfection, and the potentially wider range of environments that support mycobacterial growth.

The National Institute of Occupational Safety and Health have produced a criteria document 98-116 (NIOSH 1998) to recommend standards for occupational exposures to metal-working fluids. Although microorganisms, including *Legionella*, are mentioned as metal-working fluid contaminants, no exposure limits are currently established. This is likely to change in the near future given the increasing number of publications that link environmental mycobacteria (and most specifically *M. immunogenum*) to diseases such as hypersensitivity pneumonitis.

The specific issue of cooling towers raises interesting questions. Potentially pathogenic mycobacteria have been isolated from cooling tower water, but an epidemiological link with disease has not yet been established. As research on exposure routes to environmental mycobacteria continues, it is likely that cooling tower aerosols will be increasingly suspect as sources of infectious agents. If this is the

case, it will be instructive to see whether the extensive guidelines and regulations currently in place to reduce the legionellosis risks are equally effective in eliminating the more disinfection resistant mycobacteria.

#### 12.3.4 Institutional exposure

Essentially, management of exposure to environmental mycobacteria in hospital and health care settings is similar to management for *Legionella*. Minimize the opportunities for exposure through hydrotherapy, showering and other hot water use. In addition, point-of-use filtration on tap water used for laboratory reagents, deionized water and other hospital uses has been shown to be very effective at minimizing pseudo-outbreaks linked to *M. avium*, *M. gordonae* and *M. scrofulaceum* (Stine *et al.* 1987; Graham *et al.* 1988). Infections linked to contaminated ice-water have also been effectively controlled by cleaning and disinfection of the ice machines (Labombardi *et al.* 2002; Gebo *et al.* 2002).

Control of *Legionella* in hot water systems has received considerable attention in recent years. Temperatures above 45 °C are considered to increase risks of scalding, yet they are also at the upper temperature range for growth for both *Legionella* and the mycobacteria. Control of these pathogens can be achieved in part by storage of hot water at temperatures that kill the organisms; generally above 60 °C for *Legionella* (although the organism has been isolated from thermal effluent at 63 °C) (Fliermans *et al.* 1981). To prevent risks of scalding, hot water has to be mixed with cold water to achieve a safe temperature prior to point of use. To reduce risks from both the thermotolerant environmental mycobacteria and *Legionella*, the United States CDC and the American Society of Heating Refrigeration and Air-conditioning Engineers recommends that hot water is stored above 60 °C and “circulated with a minimum return temperature of 51 °C” (CDC 2001; ASHRAE 2000). They also recommend that cold water is stored and distributed below 20 °C to minimize growth of these organisms. These guidelines are primarily based on studies with *Legionella*, and do not appear to have been rigorously tested for their effectiveness at reducing environmental mycobacterial infections.

#### 12.3.5 The high risk groups

Both morbidity and mortality from environmental mycobacterial infections are dramatically amplified in high risk groups. As environmental mycobacteria are primarily opportunistic pathogens, this group requires the highest level of vigilance. However, it should be remembered that environmental mycobacterial diseases are increasing in populations with no predisposing factors; they have, therefore, become a public health concern for all groups. It is certainly reasonable to suggest that high risk groups (very young, elderly, immunocompromised, pregnant) should consider

minimizing exposure at public baths and spas. There are also reasonable arguments to suggest that the most susceptible should avoid consumption of tap water without point-of-use filtration (carefully regulated) or boiling. However, these are general recommendations to prevent any infection in these high risk groups and not specific for the mycobacteria.

There are specific groups of people in tropical countries who primarily through geographic distribution are susceptible to the devastating effects of Buruli ulcer (refer to Chapter 8). At present the public health response is limited to early detection and treatment as the exact routes of exposure are yet to be defined.

## 12.4 THE HACCP APPROACH TO MANAGEMENT

Can we identify a HACCP approach to managing environmental mycobacteria? The seven principles of HACCP begin with identification of hazards and preventative measures (Table 12.2).

The second step in the HACCP approach is to identify critical control points. As for any pathogen found in municipal water systems, there is a flow chart of potential critical control points from source to point of use/point of exposure: Source protection → optimization of water treatment → ensure residual disinfection → maintain distribution system integrity and water pressure → point-of-use protection (Ford 1999).

**Table 12.2** Hazards linked to waterborne exposure to environmental mycobacteria and associated preventative measures

	<b>Hazards</b>	<b>Preventative measures</b>
Identify hazards and preventative measures	Exposure to contaminated aerosols	Disinfection and microbiological filtration. Placement of cooling towers, etc.
	Aspiration of contaminated water	Disinfection and microbiological filtration. Education in bathing habits and use of, for example, whirlpool tubs
	Ingestion of contaminated water	Disinfection, microbiological filtration and monitoring programs. Education in risks from tap-water consumption, particularly for the immunocompromised
	Infection of abraded skin	Education around swimming pools and spas. Appropriate disinfection, filtration or heating
	Transmission through aquatic insects (postulated for Buruli ulcer)	Insect control programs

Source minimization of environmental pathogens is difficult due to the multiple environmental pathways of source water contamination. In other words, point source control is unlikely to be effective, with the exception of MAP (see below). Coagulation/flocculation/filtration may be effective at reducing numbers of environmental mycobacteria in drinking-water distribution. However, chlorination is unlikely to be an effective method of control due to the chlorine resistance of the organisms, and their ability to survive and possibly proliferate in protozoa and biofilms (Cirillo *et al.* 1997; Field *et al.* 1997; Hall-Stoodley 1999). Given the inability of water treatment to provide 100% removal of microorganisms, the water treatment plant is unlikely to be the most effective means of environmental mycobacterial control.

The distribution system itself can become rapidly recontaminated through leakage, back-siphonage or cross-connections (Ford 1999). With ageing water distribution systems worldwide, the only effective pathogen control within the distribution system is maintenance of sufficient water pressure (to minimize back-siphonage or cross-connection through leaks) and high levels of residual disinfection. Again, with the environmental mycobacteria, residual chlorine is considered ineffective at inactivation. In contrast to many other waterborne pathogens, where regrowth within the distribution system is minimal or does not occur, point-of-use protection would appear to be the most important critical control point for environmental mycobacteria.

For organisms whose transmission path is thought to be primarily through the inhalation route, point of use/point of exposure includes public use of municipal pools and spas, showering, hot tub use, whirlpool baths and toilet flushing. In addition, although the epidemiological link does not appear to have been made for the mycobacteria, potentially PEM have been found in cooling tower water and, therefore, cooling tower aerosols are also a potential point of exposure. Clearly, in these instances, point-of-use filtration for the drinking-water faucet is insufficient and the management options discussed in the previous sections become the critical control points.

The next steps in the HACCP approach include establishing critical limits, effective monitoring, remediation responses, evaluation and documentation; however, we are still not at a point where even critical limits and effective monitoring can be established. For each environmental mycobacterial species, these critical limits will differ. They will also be dramatically affected by the susceptibility of the exposed population. Until research has allowed us to determine the appropriate ranges of critical limits, and quantitative monitoring of the different mycobacterial species is possible, critical control can only be based on rigorous cleaning, maintenance and disinfection programs – and the absence of disease.

MAP is a special case. The organism is known to be shed in the hundreds of millions in Johne-infected cattle faeces (see Chapter 6). There is clearly a role for water management in preventing run-off from cattle feedlots entering water sources. There are also extensive HACCP related guidelines to minimize the risks of JD in

cattle. Although designed to minimize disease and its economic implications in animal husbandry, these same guidelines should also be partially protective of water sources and the hypothesized connection with human disease.

## 12.5 KEY RESEARCH ISSUES

- The public health response to MAC has been directed at disease management and not at prevention.
- Current epidemiological data fails to provide a convincing link between ingestion of water and mycobacterial disease.
- The public health response to MAP has been primarily in support of “herd management”, and a water route of exposure is not currently considered, due in part to the inability to conclusively describe the causative agent of CD.
- If comprehensive epidemiological studies can provide firm evidence that pathogenic mycobacteria are transmitted by the water route and contribute significantly to both morbidity and mortality, then the public health response is clear: 1) for drinking-water: regulations, treatment and monitoring are necessary; 2) for recreational exposures: regulations, treatment where possible, monitoring and education; 3) for institutional exposures: guidelines/strict regulations, prevention, treatment, monitoring and education; 4) for industrial exposure: guidelines/strict regulations, prevention, treatment, monitoring and education.
- For each of the above, critical control points should be identified in order to apply the HACCP approach to water management.
- Each of the above becomes particularly important where susceptible populations are involved.
- If the link between MAP and CD is firmly established, this has enormous implications for agricultural practice, and in particular discharge of wastewaters. The trend in recent years towards confined animal feeding operations has made the issue of surface and groundwater pollution particularly acute.