Emerging Waterborne Pathogens of Concern in the State of Arizona

Prepared by the

Microbial Contaminant Subcommittee

of the

Arizona Department of Environmental Quality

Advisory Panel on Emerging Contaminants

Jan 7, 2014

1.0 INTRODUCTION

1.1 Background

The Advisory Panel on Emerging Contaminants (APEC) was formed by the Arizona Department of Environmental Quality to advise water utilities and the general public on matters concerning unregulated chemicals and pathogens in water. APEC addresses chemicals and pathogens of emerging concern that threaten the continued safety of water like chemicals from pharmaceuticals and personal care products and microbial pathogens like the Naegleria parasite and Legionella bacterium. The primary goal of the APEC is to provide a forum for open discussion, prioritization, and planning related to emerging contaminant issues of critical interest to the safe use of drinking water, reclaimed water, and recycled water in Arizona.

To accomplish this goal, APEC has created three subcommittees focusing on the areas of emerging chemical contaminants, emerging microbial pathogens and a public outreach component. The Microbial Contaminant Subcommittee (Committee) is focused on identifying and providing guidance on unregulated microbial organisms detected in Arizona waters that could potentially be toxic to humans or the environment. The Microbial Contaminant Subcommittee consist of subject matter experts representing the fields of water and wastewater utilities, health departments, public health laboratories, environmental quality experts and professors specializing in pathogenic organisms.

1.2 Determination of Emerging Microbial Contaminants

The term *emerging microbial pathogen* is not intended to infer any "new" pathogenic organisms but rather to represent a group of organisms that currently are not regulated but appear to be *re-emerging* and occurring with increased frequency or severity. The World Health Organization (WHO) defines "emerging infectious diseases" as resulting from newly identified and previously unknown infections, which cause public health problems either locally or internationally. SARS is a good example of what could be considered an emerging (new) infectious disease. Likewise, the WHO defines "reemerging infectious diseases" as those that are demonstrating reappearance through an increase in the number of infections from diseases which had previously caused so few infections that it had no longer been considered a public health problem. Nevertheless, the terms *emerging* and *reemerging* will be used interchangeably herein so as to avoid confusion.

Arizona communities have a long history of responding to emerging pathogens. West Nile virus and the hantavirus are just two recent examples of pathogenic organisms that until the last decade, were virtually unheard of. Through increased public awareness, best management practices and local health departments that remain actively engaged, disease outbreaks resulting from these organisms have been successfully contained. It is our hope that a comprehensive public awareness campaign can achieve similar results in successfully addressing waterborne emerging pathogens.

To help increase public awareness about these organisms and potential risks, the Committee created a candidate list of emerging pathogenic microorganisms that have demonstrated a potential to impact Arizona communities in a negative manner by causing illness, community-wide outbreaks, and even death. In determining which pathogenic organisms to include in the emerging contaminant list, the Committee developed a screening criteria consisting of the following;

a. Microorganism is currently not regulated at the state or federal level.

b. Demonstrates an increased frequency of occurrence both in Arizona and/or nationwide.

c. Demonstrates the ability to cause serious illness and/or death.

d. Demonstrates the ability to spread via contact with sources of water.

e. Organisms are shed into the environment in high numbers, or they are highly infectious to humans at low doses.

Pathogenic organisms meeting any one of these criteria are considered to pose a significant potential risk to public health to warrant inclusion as an emerging microbial contaminant.

2.0 EMERGING MICROBIAL PATHOGENS FOUND IN ARIZONA WATERS

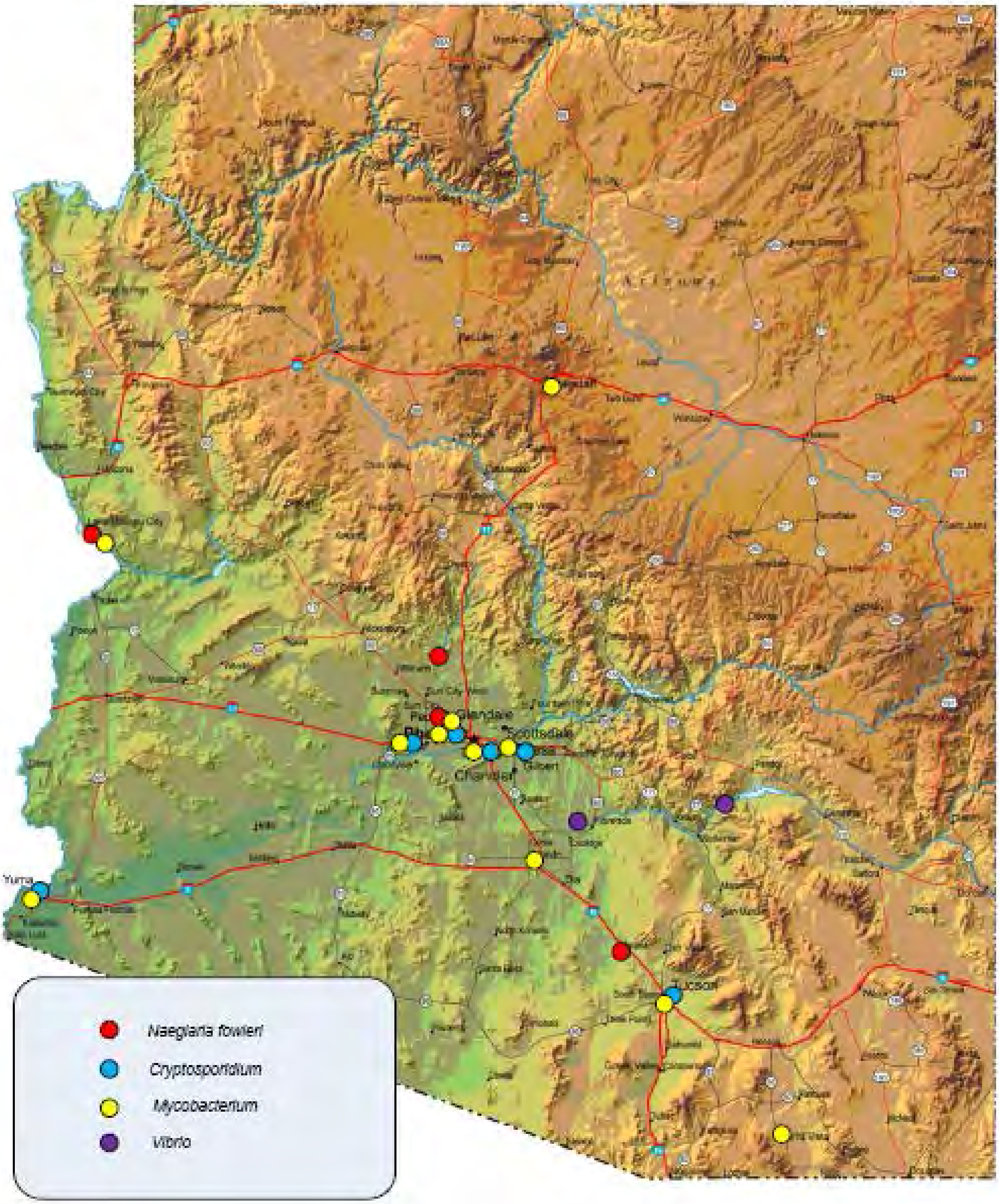
2.1 Emerging Contaminant List

The following pathogens were chosen by the committee and are considered to be emerging, or re-emerging, in both frequency and severity. These pathogens have appeared both in Arizona and nationwide within the past decade and pose health risks for Arizona communities.

Contaminant	Description
• *Naegleria fowleri*	Protozoan parasite found in shallow, warm surface and ground water causing primary amebic meningoencephalitis often resulting in death.
• *Legionella pneumophila*	Bacterium found in the environment including hot water systems causing lung diseases when inhaled.
• *Mycobacterium avium*	Bacterium causing lung infection in those with underlying lung disease, and disseminated infection in the severely immunocompromised.
• *Vibrio cholerae*	Can cause extensive gastroenteritis. Recent outbreaks have occurred within the Native American communities located along the Salt and Gila Rivers.
• *Cryptosporidium*	Protozoan parasite responsible for over 40 pool closures/outbreak each year. Spores are very resistant to chlorine. Symptoms of illness show up from two to 10 days after infection and include vomiting, diarrhea, dehydration and fever.

2.2 Where are they found in AZ

Reported Cases 2002-2013



Naegleria fowleri

Description

Naegleria fowleri is a free-living ameboflagellate commonly found in warm bodies of water such as ponds, irrigation canals, lakes, hot springs and moist soils worldwide. While *N. fowleri* is commonly found worldwide, infections are extremely rare yet highly fatal with a mortality rate over 99%. Exposure to *N. fowleri* typically occurs when inadequately disinfected water enters the nose and causes a disease known primary amebic meningoencephalitis (PAM), a brain infection that leads to the destruction of brain tissue causing brain swelling and death within a few days, hence the name "brain eating amebae" that often appear in headlines.

N. fowleri has been associated with five deaths traced to water in Arizona since 2001 and three deaths in Louisiana since 2011. There have been 35 total cases of *N. fowleri* infections reported in the U.S since 2001 with each incident resulting in fatality.

Health Effects

Initial symptoms of PAM start one to seven days after infection. The initial symptoms include headache, fever, nausea, vomiting, and stiff neck. Later symptoms include confusion, lack of attention to people and surroundings, loss of balance, seizures, and hallucinations. After the start of symptoms, the disease progresses rapidly and usually causes death within one to twelve days.

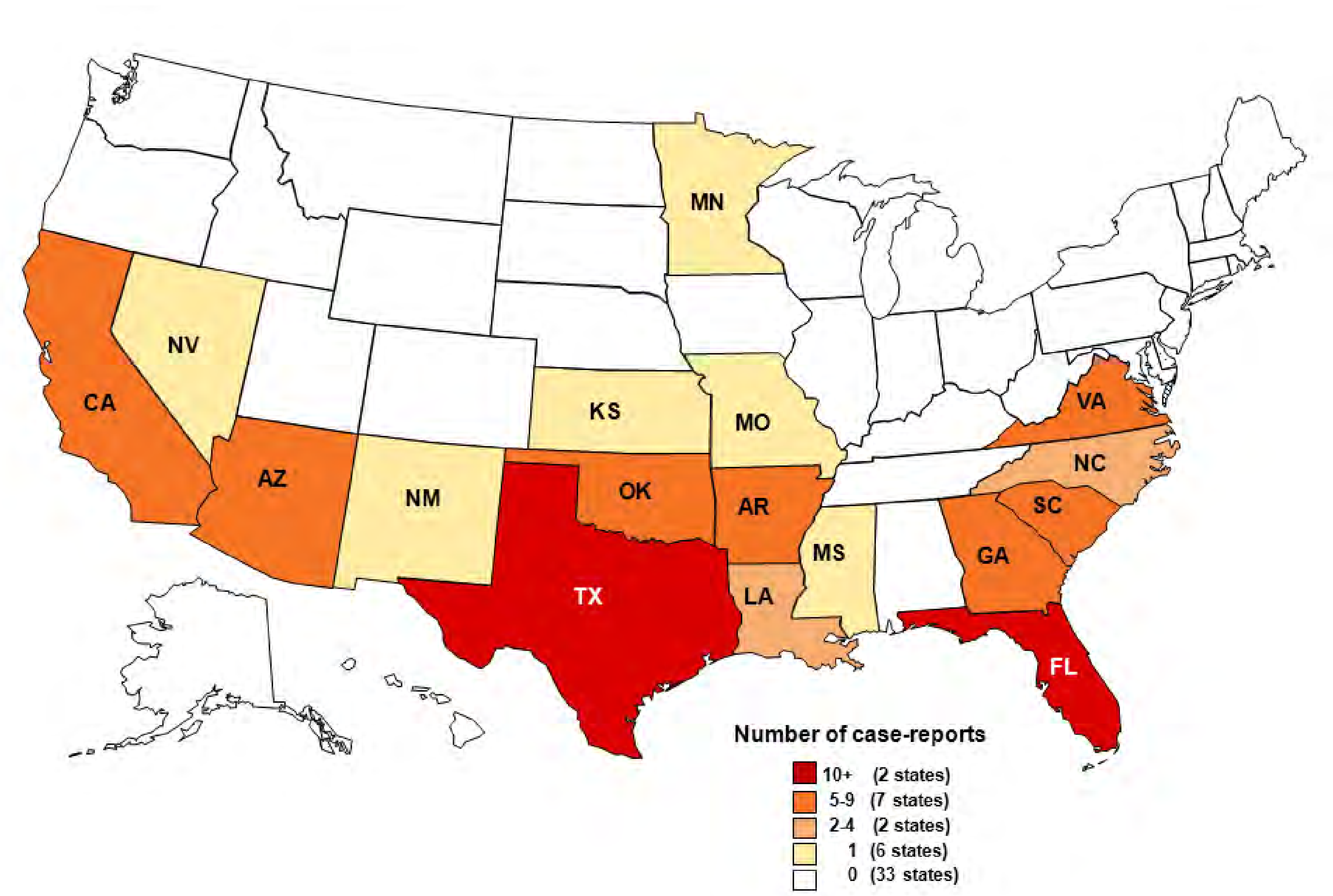
Exposure

N. fowleri infections do not result from drinking contaminated water. Exposure resulting in infection is commonly associated with forced entry of water up or through the nose via jumping, diving, water skiing or the use of nasal/sinus rinse therapies. According to the CDC, personal actions to reduce the risk of *N. fowleri* infection should focus on limiting the amount of water going up a person's nose and lowering the chances that *N. fowleri* may be in the water.

Due to the thermophilic nature of the *N. fowleri* organism, infection is most likely to occur during the summer months of July, August and September when air and water temperatures are elevated. *N. fowleri* infections are more common in the southern states such as Arizona, Texas, Florida and Louisiana due to the thermophilic nature of the organism. As a result, infections usually occur during periods of prolonged hot temperatures which often result in higher water temperatures and lower water levels. *N. fowleri* infections are not contagious and cannot be spread from person to person contact.

The following graphic was obtained from the Center for Disease Control and depicts historical incidences of *N. fowleri* infections since 1962. Arizona is represented as having only total 5-9 infections during this period. However, as previously mentioned, five of these cases have occurred in the last decade thus elevating *N. fowleri* on our list of emerging contaminants. The same trend can be stated for Louisiana which has experienced two lethal infections in 2013 and Florida with three lethal infections in 2007.

Number of Case-reports of Primary Amebic Meningoencephalitis by State of Exposure: United States, 1962-2011



BMP Treatment Technologies

Although PAM generally occurs after recreational exposure to contaminated water, fatal cases in both Arizona and Louisiana have been linked to domestic drinking water supply sources. Even though *N. fowleri* is easily killed via chlorination, it has been shown to persist within distribution system biofilms, despite chlorination. This occurs because biofilms provide a substrate for the growth and survival of potential pathogens therefore controlling biofilms within the distribution system appears to be a key factor in controlling *N. fowleri* as well as other amoebae.

Distribution system operators should presume that the infectious organism such as *N. fowleri* may be present and therefore practice operational guidelines to help reduce the risk of exposure to the possible presence of amoeba like *N. fowleri*. Best Management Practices are recommended for optimal distribution system operation consist of the following;

- Proper choice of plumbing construction materials and operational practices will reduce the accumulation, survival and spread of *N. fowleri*.

- Reservoirs should be visually inspected at least once every two years prior to summer operations and power washed and disinfected if visible sediment and/or biofilms are present.

- Distribution system residual disinfectant levels should be maintained at a minimum of 0.5 mg/L with an optimal level of 0.75 – 1.25 mg/L.

- Distribution systems should be unidirectionally flushed at least once every three years. Dead-end lines, slow flow areas and water mains that have historically low residuals <0.5 mg/L and/or visible sediment, should be flushed on a more frequent basis as required to maintain chlorine residuals and remove sediments.

- Groundwater wells testing positive for amoebic plaque growth should be disinfected and re-sampled for amoebic plaque growth and total coliforms to verify the absence of coliforms and amoebic activity.

- If amoebic activity persists the well should be further cleaned, disinfected and resampled until a negative result is achieved.

Routine Assessment Screening
Waterborne amoeba are not routinely targeted for analysis in water supply systems. Therefore periodic testing for the presence of indicator organisms, including *N. fowleri,* should become a standard operation practice for all drinking water systems, especially if any of the following conditions apply;

- Before and after system maintenance.

- Areas prone to dead zones.

- When water temperatures are above 75° Fahrenheit.

Prevention and Control
Even though hundreds of millions of visits to swimming venues occur each year in the U.S., it is unknown why certain persons become infected with the amebae while millions of others exposed to warm recreational fresh waters do not, including those who were swimming with people who became infected. Currently no method exists that accurately and reproducibly measures the numbers of amebae in the water making it unclear how a standard might be set to protect human health or how public health officials would measure and enforce such a standard.

Likewise, there are no known means to control naturally occurring *N. fowleri* levels in lakes and rivers making prevention to exposure difficult. Therefore, recreational water users should assume that there is always a low level of risk whenever they enter warm freshwater lakes, rivers, and hot springs, particularly in southern-tier states. The only certain way to prevent a *Naegleria fowleri* infection due to swimming is to refrain from water-related activities in shallow, warm freshwaters, particularly irrigation canals. Routine public education in advance of the summer swim season might be helpful.

Legionella pneumophila

Description
Legionella is responsible for the disease legionellosis, or Legionnaires' Disease, a severe respiratory illness characterized by pneumonia. Approximately 1,000 cases are reported annually to the CDC, but it is estimated that over 25,000 cases of the illness occur each year resulting in more than 4,000 deaths. The largest outbreak occurred in Philadelphia, PA in 1976, where 220 cases and 34 deaths were reported.

Although *Legionella* is ubiquitous in the environment, it only causes legionellosis when inhaled as an aerosol or mist. Legionellosis is not contagious and drinking contaminated water does not cause illness. However, aspirating contaminated water is the main source of infection.

Most outbreaks since 1976 have been linked with hospital water distribution systems (AWWA, 1999). Death rates reported annually have increased 217% during the past decade from 1,110 in 2000 to 3,522 in 2009. Preventing and controlling *Legionella* can be particularly troublesome for large hotels, hospitals and office buildings tasked with maintaining central mechanical facilities for heating, cooling and water distribution as *Legionella* proliferates in artificial environments such as cooling towers, evaporative condensers, whirlpools, and hot water tanks. These environments act as amplifiers or disseminators of *Legionella pneumophilia*. Recent studies have demonstrated *Legionella* to be present in 64% of the biofilm samples studied for amoebic activity.

Health Effects
Symptoms of *Legionella* are typically characterized by malaise, headaches, coughs and fever and over 90% of cases are caused by *Legionella pneumophilia SG1. Legionella* primarily affects the elderly, smokers and individuals with stressed respiratory function. Approximately 87% of all reported cases were age >40 years with men twice as likely as women to be afflicted. Children under 15 years of age are rarely afflicted although there is emerging evidence of pediatric legionellosis (Neonates).

Exposure
Since aspiration of contaminated water appears to be the main route of infection, sources that are prone to the creation of water mists are the primary exposure routes. These include showers, aspirating water, water features, spas, washing areas, cooling towers and any activity where deliberate agitation of water produces an aerosol above the water surface or surrounding area.

BMP Treatment Technologies
Since most historical outbreaks can be traced back to hospitals, hotels and buildings, most BMP strategies are directed towards facilities management functions for operation of those facilities. Facility owners are responsible for water safety once the water enters the facility and large, complex systems are more prone to *Legionella* growth than smaller systems. Secondary disinfection coupled with managing stagnant water

conditions and water temperature is one of the most effective approaches for reducing these risks. Routine assessment screening of water systems is also an effective approach.

It is recommended that facilities create routine assessment screening through the creation of a hazard assessment team. Hazard analysis for critical control points has repeatedly been proven as an effective approach for ensuring public health. Identification of critical control points and implementation of preventative control measures will ensure adequate protection of and reduce risks. As an added benefit, control measures for *Legionella* will also reduce risk for most other biological hazards as well.

The team should include up to ten members who will oversee the plan and make key decisions. Appoint a team leader who will oversee the plan and ensure it is followed. Some examples of key individuals within different organizations are as follows.

HEALTHCARE (*Hospitals, clinics, long term care facilities)* **Team Members**

Facilities director
Administrator
Infection control
Health & Safety
Environmental Services
Medical director
Chief Engineer

INSTITUTIONAL *(Schools, Hotels, Casinos, etc.)* **Team Members**

Facilities director
Health & Safety
Housekeeping
Maintenance & Engineering

INDUSTRIAL *(Pharma, Manufacturers, etc.)* **Team Members**

Facilities director
Health & Safety
Maintenance & Engineering

Step 1: Identification Critical Control Points

Different stages throughout the process flow diagram should be evaluated not only for areas of potential growth but also those areas that have potential for aerosol release and exposure. Process flow diagrams should and inventory should be validated with a thorough walk through. Items for consideration include, but are not limited to, the following;

- Domestic services (potable) Water heaters
- Water storage
- Points of Use (POU) Sinks, showers, etc.
- Cooling towers

- Pools & Spas
- Decorative fountains
- Water filters
- Irrigation
- Plumbing & distribution
- Ice machines
- Cross-connections
- Fire protection
- Swamp coolers
- Drinking water fountains & coolers
- Other water using devices

Step 2: Control Measures
Implement control measures that are evidence based industry best practices proven to be effective for reducing risk associated with *Legionella.* Control measures should be documented through building automation systems, preventative maintenance and housekeeping work orders, vendor reports and logs.

Step 3: Monitoring
Monitoring is necessary for verifying the effectiveness of the control measures. Establish a reasonable monitoring frequency using industry established guidelines and set critical control limits for routine operation.

Step 4: Contingency Plans
Define and establish corrective actions when critical control limits are not met.

Cooling Tower BMPs

The following treatment strategies are demonstrated BMPs for cleaning and disinfection of cooling towers. These BMPs reflect both off-line and on-line activities that can be performed as seasonal maintenance or as a contingency to particular situation.

OFF-LINE (Seasonal)	ON-LINE (Remedial)
✓ **Dose to achieve 10 ppm free halogen and maintain 5 ppm free halogen for 6 hours** ✓ **Alternatively, dose to achieve 25 ppm free halogen and maintain for 1 hour** ✓ **Apply biodispersant (optional)** **Recommended for seasonal off-line cleaning and disinfection and in response to heavy persistent microbial activity. Also recommended at startup and shutdown.**	✓ **Maintain 5 ppm free halogen for 6 hours** ✓ **Apply biodispersant (optional)** **Recommended for periodic on-line disinfection to respond to heavy biofouling, process leaks, or other issues that may contribute to excessive microbial activity.**
OFF-LINE (Emergency)	**ON-LINE (Shock Dose)**
✓ **Dose to achieve 25-50 ppm free halogen and maintain 10 ppm free halogen for 24 hours** ✓ **Apply biodispersant** **Recommended for emergency disinfection in response to an outbreak situation or heavy persistent microbial activity.**	✓ **Dose to achieve 5 ppm free halogen** ✓ **Apply biodispersant (optional)** **Recommended for periodic on-line disinfection to respond to persistent biofouling, process leaks, or other issues that may contribute to excessive microbial activity.** **May also be used weekly or monthly as a pre-emptive control strategy during warmer summer months when microbial activity is high.**

Ornamental Fountain BMPs

- ✓ Avoid idle periods
- ✓ Avoid accumulation of sediments
- ✓ Watch out for heat sources such as lights
- ✓ Keep system treated to control biofilms
- ✓ Monitor system to ensure treatment is effective
- ✓ Clean and disinfect system 2x per year or more if necessary

Pool and Spa BMPs

- ✓ Exchange 505 of the water each day
- ✓ Use sand filters and backwash each day
- ✓ Total volume turnover should take not more than six minutes
- ✓ Paper or polyester filters should not be used
- ✓ Treat continuously with an oxidizing biocide injected prior to the filter
- ✓ When chlorinating biocides are used, target 3-5 mg/L (ppm) free chlorine
- ✓ Pumps and disinfection system should be run 24-hours per day
- ✓ Residual disinfectant concentration and pH should be measured before use and every two hours during use.
- ✓ Pool waters should be tested for microbiological growth monthly
    - Colony count at 37°C should be <100 CFU/mL and preferably < 10CFU/100mL
    - There should be <10CFU/100mL Pseudomonas aeruginosa per 100mL
    - There should be no coliforms of Escherichia coli in 100 mL

Recreational Waters

- ✓ Recreational water has rarely been implicated in an outbreak of legionellosis.
- ✓ Systems should be maintained to a high standard as defined by local health code requirements.
- ✓ Be aware that legionellae have been found in pool water filters and therefore proper pool filter maintenance is essential.
- ✓ Be aware of potential biofilm formation on semi-wetted surfaces and keep surfaces clean and disinfected.
- ✓ Be aware of rinse showers in the vicinity of the pool and ensure these showers are used frequently to avoid stagnation and biofilm growth.

Routine Assessment Screening

Although not required, testing is highly recommended to verify control practices. Random testing in the absence of an assessment or management program is unwise, and annual "spot checks" are rarely if ever meaningful. Legionella testing should be combined with other monitoring strategies.

Routine assessment for the presence of Legionella is performed via laboratory culturing. ISO Method 11731 is the preferred method for quality, consistency and standardization however not all labs utilize ISO 11731. The test requires up to 12-14 days and bacteria colonies are confirmed via serotyping. The following screening frequency provides a good basis for routine monitoring.

System	Frequency
Cooling Water	Quarterly
Domestic Hot Water Storage	Monthly to Quarterly
Domestic Showers	Monthly to quarterly
Sink Outlets	As needed

Routine assessment and secondary disinfection are extremely effective for controlling contamination and ensuring public health. In addition to Legionella, other common infections linked to domestic water systems include;

- Pseudomonas aeruginosa
- Stenotrophomonas maltophilia
- Acinetobacter species
- Aeromonas species
- Non-Tuberculosis Mycobacteriums (NTM)

Secondary disinfection is therefore an excellent strategy for controlling these infectious organisms and can consist of any number of the following strategies.

- ✓ Super heating and flushing lines
- ✓ Hyperchlorination
- ✓ Continuous chlorination
- ✓ Chloramine addition
- ✓ Copper-silver ionization
- ✓ Ozone
- ✓ Ultra-Violet radiation

Cryptosporidium

Description

Cryptosporidium is included as an emerging parasitic protozoan pathogen because its transmission has increased dramatically over the past two decades. Evidence suggests the disease is spread via increasingly popular day-care centers, water distribution systems, public pools and institutions such as hospitals and extended-care facilities for the elderly. *Cryptosporidium* first became recognized in humans at the start of the AIDS epidemic in 1982 where it was responsible for causing potentially life-threatening disease in the growing number of immuno-compromised patients.

Health Effects

Cryptosporidium induces the disease cryptosporidiosis, which is capable of producing unpleasant gastric and diarrheal illness (Rose, 1997). The parasite's transmittable spherical shaped oocyst which contains a hardy thick wall. *Cryptosporidium* was the cause of the largest reported drinking water outbreak in U.S. history, affecting over 400,000 people in Milwaukee in April, 1993. More than 100 deaths are attributed to this outbreak. In 1994, Las Vegas experienced an outbreak infecting approximately 78 people. *Cryptosporidium* remains a major threat to the U.S. water supply.

Although chlorine is effective against most vegetative bacteria and viruses when used at the normal concentration for treatment, it will not inactivate *Cryptosporidium* oocysts.

Exposure

The oocyst is spread through the feces of infected humans and animals, including mammals, birds, reptiles, and fish. *Cryptosporidium* is frequently waterborne in nature and infections have occurred through contact with contaminated drinking water supplies, as well as zoonosis (animal person contact), contaminated food, contaminated swimming pools, and other recreational waters. Oocysts may be present in animal slurry spread on farmland as fertilizer. Consequently, runoff from rain carries oocysts into streams, lakes, and other reservoirs. Sewage is another source. The infective dose varies from less than 30 oocysts to as many as one million oocysts. These patients are prone to severe and protracted diarrhea which can persist for months with considerable weight loss and mortality (Gerba *et al.*, 1996; Rose, 1997).

BMP Treatment Technologies

Water distribution systems with high concentrations of *Cryptosporidium* in their source water may adopt alternative disinfection methods (e.g., ozone, UV, or chlorine dioxide). However, most water systems are expected to meet EPA requirements while continuing to use chlorination. Regardless of the primary disinfection method used, water systems must continue to maintain residual levels of chlorine-based disinfectants in their distribution systems.

Routine Assessment Screening

It is likely that EPA's Long Term 2 Enhanced Surface Water Treatment Rule will include source water monitoring for Cryptosporidium; inactivation by all unfiltered systems; and additional treatment for filtered systems based on source water *Cryptosporidium* concentrations. EPA will provide a range of treatment options to achieve the inactivation requirements.

3.0 RECOMMENDATIONS FOR UTILITIES

The use of chlorine disinfection has made an immense contribution to the safety of drinking-water supplies, yet, recently, the limitations of chlorine and some disadvantages linked to its use have been widely publicized:

Although chlorine is effective against most vegetative bacteria and viruses when used at the normal concentration for treatment, it will not inactivate *Cryptosporidium* oocysts. Furthermore, chlorine has a very limited effect upon pathogens growing in biofilms. So while its use reduces overall risks, it changes the relative impact of different pathogens. Traces of chemical by-products of chlorine disinfection have raised public concern about potential long-term but small risks from chemically treated water. Inappropriate decisions made about the risks from chemical contamination versus the need to maintain microbiological safety to protect consumers from imminent high microbial risks have been implicated in the re-emergence of pathogens.

Possibly the most revolutionary advance in analytical technology during the last 30 years was the discovery of a simple, but effective method of amplifying very specific regions of an organism's genetic material. The technique, called the Polymerase Chain Reaction (PCR), is now widely used in medical, forensic and environmental laboratories. Not only does the method allow investigators to discriminate between micro-organisms from different sources, it can be used to detect extremely small quantities of the nucleic acid: equivalent to a single micro-organism. Detection of nucleic acid by PCR does not necessarily indicate that viable infective organisms are present, but it is an excellent exploratory tool

A significant number of the viruses associated with water-related disease outbreaks cannot be grown in the laboratory using conventional culture techniques. The use of PCR methods for the analysis of pathogens in water has been fundamental to our understanding of the distribution of some of the most important water-related viral pathogens: for example noroviruses, rotaviruses and hepatitis E virus. Other recently-developed technologies are being assessed for their application in water microbiology. Flow cytometery is a powerful technique using laser light to quantify particles or to recognize structural features of cells. By measuring the scatter and wavelength of light as a particle intercepts the beam, information can be gained that allows the rapid quantification of the organisms. The analytical capability of the technique can be further enhanced by use of fluorescent monoclonal antibodies that are specific for a particular pathogen. Using this, and other fiber optic technologies, we are presented with the potential to detect and quantify water-related pathogens in real time. The implications of these advances to the management of water quality and the protection of public health may be far reaching.

The recognition of emerging and re-emerging pathogens does not rely solely upon the development of new analytical methods. The reassessment of methods in the context of improved knowledge about the health risks from water-related disease leads to evolving interpretation of findings. This is a feature of many of the publications listed throughout this brochure.

WHO has recognized the limitation of many established methods for monitoring water quality when it comes to predicting the presence of known pathogens. New approaches to health-related monitoring are being introduced that can overcome many of the weaknesses of current methods and provide additional tools for reducing disease risks. Water Safety Plans (WSPs) are an approach to drinking-water safety management that has its roots in the multiple barrier principle of water treatment, and the Hazard Assessment of Critical Control Points (HACCP) approach to the safety of foods. The primary objectives of a WSP in ensuring good drinking-water supply practice are the prevention of contamination of source waters, the reduction or removal of contamination through treatment processes to meet health-based targets, and the prevention of contamination during storage, distribution and handling. WSPs are a central component of the 3rd edition of the WHO *Guidelines for Drinking-water Quality*. This approach to water quality management presents challenges for process monitoring and puts new demands on analysis.

Biofilm Management

Biofilm is a complex mixture of microbes, organic and inorganic material accumulated amidst a microbially produced organic polymer matrix attached to the inner surface of distribution system.

Source water may contain high levels of calcium carbonate, iron, or manganese, creating “hard water.” If the hardness is not removed at the water treatment plant, biofilm and scale can form on the inner walls of the distribution pipes.

• The formation of biofilm is dependent on the type of pipes, whether iron, poly vinyl chloride (PVC), or concrete lined. In turn, biofilm and scale can affect the life span of the pipes, thus playing a role in the cost of the distribution system infrastructure.
http://www.epa.gov/nrmrl/news/news092007.html

Disinfectants (typically chlorine) introduced during the treatment process may react with organic carbons naturally present in the source water to form unwanted disinfection by-products (DBPs).

• Biofilm and scale can decrease concentrations of disinfectants. They can also cause taste and odor problems and harbor disease-causing microorganisms or chemical pollutants, possibly releasing them into drinking water in distribution systems.
USEPA REPORT 2002

Health Risks from Microbial Growth and Biofilms in Drinking Water Distributions Systems The report lists 11 primary bacterial pathogens and 11 opportunistic bacterial pathogens detected in water distribution systems and/or biofilms
http://www.epa.gov/safewater/disinfection/tcr/pdfs/whitepaper_tcr_biofilms.pdf

Measures for Controlling Biofilm Development
• Nutrient control
• Control of contamination from materials and equipment
• Control and mitigation of system hydraulic problems
• Cross-connection control and backflow prevention
• Disinfectant residuals
• Corrosion control
• Infrastructure replacement and repair
• Storage vessel management and alteration
http://www.epa.gov/safewater/disinfection/tcr/pdfs/whitepaper_tcr_biofilms.pdf

Mycobacterium

Description

Mycobacterium infections are traditionally associated with decreased respiratory function and in the early 1900's, Arizona was a preferred destination for tuberculosis treatment as a result of our warm, dry climate. While tuberculosis is no longer a widespread concern, there are still persistent infections originating from a variety of sources of mycobacterium commonly known as nontuberculous mycobacterium (NTM). NTM bacteria are ubiquitous in the environment and commonly associated with water and soil.

- *M*. avium-intracellulare complex (MAC)
- *M. kansasii*
- *M. scrofulaceum,*
- *M. fortuitum*
- *M. marinum*
- *M. kansasii*
- *M. chelonae*
- *M. porcinum*

The prevalence of nontuberculous mycobacteria is increasing nationwide although the reasons are not known. Nontuberculous mycobacteria infections are not contagious and are not spread via person-to-person contact and it is unknown why the germ makes some people sick and does not affect others, but doctors believe that people with underlying diseases or damaged lungs are most likely to get these infections.

Nontuberculous mycobacterium infections can become chronic and require extensive ongoing treatment of at least a year with strong antibiotics. While detailed statistics are not available, scientists estimate the people who get nontuberculous mycobacterium infections are mostly women and the vast majority are white.

Health Effects

Because NTM diseases are not reportable, information regarding the occurrence of disease outbreaks is likely underestimated. However, human infections due to NTM appear to be increasing at a significant rate across the United States. CDC estimates that NTM diseases (non-AIDS related) occur in 1.8 out of 100,000 individuals per year in the U.S., of which approximately 72% are attributable to *M. avium* complex (MAC).

It has been estimated that in the U.S., 25% to 50% of individuals with AIDS will develop NTM diseases, primarily attributable to MAC. The recent use of highly active anti-retro viral therapy (HAART) in AIDS patients suggests a decrease in the risk and rate of NTM infections in these individuals.

Waterborne NTM have been associated with hospital (nosocomial) outbreaks worldwide. These disease outbreaks usually involve sternal wound infections, plastic surgery wound infections or post injection abscesses. Mycobacterial infections in patients undergoing dialysis treatment have also been reported. Although not reported frequently, some outbreaks of mycobacterial infection have been reported after exposures in public swimming areas.

Exposure

NTM species have been isolated from numerous water sources, including waste water, surface water, recreational water, ground water and tap water. Piped water supplies are readily colonized by mycobacteria. Biofilms may serve as a reservoir for these opportunistic pathogens. Exposure pathways of potential concern include ingestion, inhalation and entry of organisms through abraded skin.

Common clinical syndromes include:

- Pulmonary infection
- Infection of the lymph nodes
- Ear infection
- Skin & soft tissue infection
- Catheter-associated infection
- Whole Body (e.g., blood) infection

In general, symptoms seen in children are similar to those reported in adults. The most common form of clinically significant NTM infection in children is infection of the lymph nodes in the neck. Pulmonary disease is relatively rare in children.

BMP Treatment Technologies

NTM are relatively resistant to standard water disinfection procedures and therefore readily occur in potable water systems. They have often been referred to as the 'ducks of the microbial world' due to their thick, waxy, outer coating which enables them to thrive in aquatic environments. NTM are not transient contaminants of drinking water distribution systems and readily grow and persist in plumbing lines with increased distance from the treatment plant.

In general, two mechanisms can be used to eliminate microbes from drinking water consisting of removal or disinfection. Removal treatments include filtration, sedimentation, coagulation, flocculation and adsorption and are primarily physical operations that remove bacteria from the water. Disinfection treatment technologies are designed to kill bacteria using chemicals such as chlorine, ozone, bromine, iodine or hydrogen peroxide which are added to the water, or may inactivate microbes via UV radiation.

Routine Assessment Screening

Vibrio cholera

Description
Vibrio cholera is commonly associated with salt water and brackish water environments and can be routinely cultured from fish and shellfish products. Cholera transmission via water has been very rare in industrialized nations for the past one hundred years primarily due to advances in water and sanitation systems. Cholera exposure is usually a result of travel to 3rd world countries.

In the past decade Arizona has experienced two cases of Vibrio within the indian communities along the Gila and Salt Rivers. The incidence of *Vibrio* infection transmitted through food increased 116% in 2012 as compared to 1996-1998 surveillance rates (CDC, 2012).

Most *Vibrio* infections occur in the warmer months.

Health Effects
Cholera is an acute, diarrheal illness caused by infection of the intestine with the bacterium *Vibrio cholerae*. An estimated 3-5 million cases and over 100,000 deaths occur each year around the world. The infection is often mild or without symptoms, but can sometimes be severe. Approximately one in 20 (5%) infected persons will have severe disease characterized by profuse watery diarrhea, vomiting, and leg cramps. In these people, rapid loss of body fluids leads to dehydration and shock. Without treatment, death can occur within hours.

Exposure
The highest rate of infection was observed in adults aged >65 years. The typical mode of transmission is through ingestion of raw or undercooked seafood, water contaminated with stool or vomitus from infected individuals, or exposing a wound to contaminated seawater. This latter mode of transmission is most often associated with fishermen.

BMP Treatment Technologies

- Sanitize surfaces exposed to seawater or seafood products.
- Thoroughly cook all seafood, especially shellfish.
- Wash hands and all utensils after contact with seafood.
- Minimize exposure to brackish waters, especially if contaminated with sewage.
- Disinfection of brackish waters is sufficient to kill *Vibrio.*
- For *V. cholera* basic sanitation is sufficient to control transmission of the disease-causing organisms.

Routine Assessment Screening