Process for Developing Microbial Standards
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Abstract
The issue of how many pathogens can be tolerated in treated drinking water supply has become a familiar discussion topic among drinking water professionals. In assessing microbial risks of drinking water, the benchmark of one infection in 10,000 people per year has often been cited as an acceptable level of risk. The US EPA currently uses the 1:10,000 annual risk of infection to develop microbial standards for drinking water.

What constitutes a minimum acceptable level of disease from drinking water is a decision that many feel should not be made solely on epidemiological or scientific grounds. Issues of public input, economics, technology, and law should be considered along with scientific data when strengthening microbial standards to make it an open and fully informed process that produces reasonable standards acceptable to the public.

This article summarizes the proposed process for determining the level of microbial risk that may be tolerated by citizens and for setting microbial standards. The proposed process, developed by a group of experts at two workshops and funded by Awwa Research Foundation, does not discuss any specific risk levels in drinking water, but rather shows a concept for setting microbial drinking water standards in which scientific, economic, and public issues are considered.

Introduction
The major public health goal for drinking water is to have adequate amounts of water for drinking and sanitation and to protect consumers from harmful contaminants and pathogens. What “safe” means in this context can and has been interpreted several ways by public health officials, drinking water utilities, legislative bodies, regulatory agencies, and the public. Both nationally and locally, consumers have their own opinions on what constitutes safe drinking water.

The issue of how many pathogens can be tolerated (physically vs. perceptually) in a finished drinking water supply has become a familiar discussion topic among drinking water professionals. In assessing microbial risks of drinking water, the benchmark of one infection in 10,000 people per year has often been cited as an acceptable level of risk. The US EPA currently uses the 1:10,000 annual risk of infection to develop microbial standards for drinking water. This number was the initial basis for the current Surface Water Treatment Rule (SWTR) but was applied only to systems serving population of more than 100,000. The estimated acceptable risk level was developed in the late 1980s and appears to have arisen from the following conceptual process (Haas, 1994):

- The treatment practices of the mid to late 1980s were considered to be producing water of an acceptable level of risk
- Based on reported disease outbreaks, the population infection burden from drinking water was approximating 1 case per 10,000 people per year
- Infection rather than illness was used as an endpoint since it is known that many illnesses go unreported and that certain segments of the population are more susceptible than others

Additionally, if one uses morbidity ratios (ratios of ill to infected persons) and mortality ratios (ratios of fatalities to ill persons) that appear to characterize many infectious diseases (for
example 50 % and 0.2 %, respectively) to calculate the lifetime risk of death due to waterborne infectious disease at a 1:10,000 risk level, it is in the $10^{-6} – 10^{-5}$ range. This is similar to the acceptable mortality from other environmental risks such as chemical exposure at most uncontrolled hazardous waste sites. However, the water-related morbidity ratio and, in particular, the mortality ratios are not well characterized for the overall US population. Moreover, what constitutes a minimum acceptable risk of disease from drinking water is a decision that many feel should not be made solely on epidemiological or scientific grounds. Today's water treatment technologies can further reduce the risk of waterborne disease, but it comes at a price that may or may not be acceptable to the majority of consumers. Issues of public input, economics, technology and law should be considered along with scientific data when strengthening microbial standards to make it an open and fully informed process that produces reasonable standards acceptable to the public.

**AWWARF workshop process**

During recent years water professionals have discussed the concept of setting the acceptable microbial risk for waterborne disease at 1:10,000. Some have called into question the validity of data that provide a basis for setting the acceptable microbial risk standard. Also, additional criteria have been suggested for establishing the level of risk that is acceptable, leading many drinking water professionals to conclude that the current risk level of 1:10,000 should be reconsidered. Consequently, water utilities requested that the basis for determination of microbial risks be re-examined by a multidisciplinary group of experts. AWWARF funded the project with the objective of convening expert workshops to develop a scientific protocol for determining the risk factor used in microbial risk assessment. At the first workshop in May 1999, participants discussed their concerns about issues such as the safety and risk of drinking water, public perception, epidemiology, and other possible issues that should be considered in determining the risk factor and its implications. At the second workshop in March 2000, the participants focused their discussion on the following areas:

- Public health
- Multiple barrier control of microbes and economic impacts
- Public perception and stakeholder involvement

Based on these discussions the expert workgroup proposed changes to the current process for setting microbial standards and for determining the level of microbial risk that may be tolerated by the public. The group of experts did not discuss any specific risk levels or factors in drinking water, but rather developed and recommended the US EPA a conceptual process for setting microbial standards in which scientific, economic, and public issues were considered.

**Discussion**

Overview of the recommended process for determination of microbial standards in drinking water.

By developing and complying with microbial standards, both the US EPA and the water utility play important roles in protecting the public from microbial waterborne diseases and infections. Figure 1 depicts a conceptual outline of the actions of the EPA and water utility required to set and maintain microbial water quality standards. The standards then become the basis for decisions by utilities about source water selection and type of treatment. Water utilities perform
some of the necessary assessment work to determine the actions needed to comply with the
standard, (i.e., source water protection, source selection, treatment availability and reliability.)
According to the new process proposed in this article and in Figure I, when the US EPA
establishes microbial standards it takes into consideration not only water treatment and water
resources issues but also many other essential factors, including epidemiological studies, public
assessment of water quality acceptability, microbial measurement methods, waterborne disease
incidence vs. exposures, social cost per illness avoided, cost as a percentage of other costs for
consumers, severity of disease by specific organism, cost and feasibility of control options.

**Figure I.** Flow diagram of involvement by the US EPA and the water utilities in setting and
measuring microbial standards.
The issues highlighted in the upper right rectangle of Figure I were those considered to be
important for setting microbial standards and for determining the level of microbial risk that may
be tolerated by the public. The workgroup developed these issues in detail and included them in
the new process recommended to the US EPA for consideration (Figure II). The proposed
process does not assume a risk level of 1 in 10,000 but rather provides a conceptual idea of a
process with description of all issues to be integrated in it.

**Figure II.** The recommended process for determining microbial risk levels and standards for
drinking water.
As shown in Figure II, the data acquisition on public health issues is done at the same time as the
assessment of the multi-barrier control system, which includes source water, treatment, and
distribution system water quality programs (Step 1). While the data on water systems and public
health are being collected, utilities and regulators involved in those two concurrent activities
communicate and provide a constant feedback to each other. At the end, the knowledge of multi-
barrier protection of drinking water and all relevant public health issues are integrated into
several options of public health protection strategy, upon which cost and benefit evaluation is
performed (Step 2). With all the information from Step 1 and Step 2, the process enters the
public and stakeholder phase, in which both groups would have an opportunity to provide input
and comment on the presented options of microbial risk levels and standards or, in other words,
the desired public health protection (Step 3). Although the proposed process seems logical, only
parts of it are used in setting standards currently. The recommended process proposes new and
innovative ways to look at issues of public health protection, multi-barrier control, and public
perception and stakeholders involvement that pertain to the steps in the process presented in
Figure II. Following is a detailed discussion of all three steps, divided into three areas based on
their significance to the entire process (Table I). For example, under the public health issue not
all topics that relate to the process of microbial standard setting are equally important. Thus the
discussion is divided into essential, important, and nonessential topics, defined as:

- **Essential issues proposed to the US EPA for consideration** are issues/factors that the
  expert group believed **must be used** by the EPA in setting the risk level for microbial
  contaminants.
- **Important issues proposed to the US EPA for consideration** are issues/factors that the
  experts group believed **should be considered as important** in setting the microbial risk
  level for microbial contaminants.
Nonessential issues proposed to the US EPA for consideration are issues/factors that the expert group believed should be taken into consideration by the EPA depending on strength and availability of the data. Based on these definitions, the workgroup then expanded Steps 1-3 in detail (Table I) that are described in the following section.

Table I. Recommended issues to be considered by the US EPA in the process of microbial drinking water standards setting:

**Breakout of the proposed issues**

**Public Health Issues**

*Introduction*
The current approach to setting microbial standards for drinking water suffers from a number of limitations, one of which is a single risk level for all microorganisms. This approach may lead to very different levels of risk for different microorganisms. For example, a 1 in 10,000 annual risk of infection for Norwalk virus, which can lead to mild diarrhea, is very different from a 1 in 10,000 annual risk of infection for hepatitis A virus, which leads to a much more severe illness. Another limitation is that the current method considers risk of infection rather than disease, the latter being a better indicator of impact. Thus, a different approach that incorporates best available information about the severity and duration of illness from each organism would be desirable, as it would give a better indication of the public health impact. As recommended here, the Quality-Adjusted Life Years (QALY) method incorporates these elements and has several advantages over the current approach:

- It weighs the severity of the disease; i.e., factors the relative value of type of illnesses by the severity and the costs associated with the different outcomes from that illness, from mild to death, from acute treatment to chronic disability
- It takes the duration of illness into account;
- It allows one to do substitution risk analysis between the disease burden associated with current water quality and the potential or known adverse effects associated with water treatment alternatives, e.g., disinfection by-products formation;
- It allows analysis of the general population independently of sensitive populations and/or based on the combined risks of both general and sensitive populations;
- It facilitates risk communication to lay audiences.

*Essential Public Health Issues for Consideration*

Essential elements to be considered in determining acceptable microbial risk for both the general and sensitive sub-populations include the following:

- Identifying organisms that are potentially transmitted via water
- For each organism, characterizing the spectrum of disease caused, (e.g., percent of asymptomatic, mild, moderate, severe, chronic sequelae, delayed manifestation, and secondary transmission)
- For waterborne disease outcomes for which causative agents are not identified (e.g., diarrhea), characterizing the spectrum of disease
- Determining the disease burden in the population due to water for each microorganism or disease of unknown etiology
- Calculating the actual QALY based on occurrence and calculated infection of actual disease
- Determining whether the QALY for each microorganism or disease is acceptable through public communication (see also the section on public perception and stakeholders’ involvement)
- If it is not acceptable, regulators will determine the appropriate water treatment or control strategy and associated costs. This will require a determination of the microbial dose corresponding to a given level of reduction in health impact (i.e., QALY).

An acceptable QALY will be determined by the level of health impact that a consumer is willing to accept as well as the costs associated with reducing that impact to acceptable levels.

**Nonessential Public Health Issues for Consideration**

There are many data elements that would be desirable for assessing the risk of acquiring infectious organisms from water and quantifying their associated disease burden. However, it is recognized that many of the key data elements are generally not available. These include dose response for sensitive populations, estimates for chronic sequelae, or delayed responses to infection such as diabetes and arthritis. Some estimates of these variables may be available by extrapolation from outbreaks or perhaps animal models. In the absence of data, experts from academia, industry, and the government should be consulted for new data and their estimates of disease burden.

**Final guidance to the US EPA on the inclusion of the public health issues in the process of determining microbial standards in drinking water**

Waterborne disease risk should be consistent in all localities regardless of utility type, community size, and water sources. Standards should be set at the national level and the states charged with the responsibility to implement the standard.

Determination of the QALYs should be done for each microorganism/disease of concern. Consideration should be given to releasing regulations for related contaminants, whether chemical or microbial, for which common control and treatment methods may be employed. Methods used for calculating QALY by the National Institute of Public Health and the Environment in the Netherlands, the European Commission, and the World Health Organization should be reviewed for their potential use as guidance in the U.S. policy. However, disease costs and other adjustments in QALY calculations specific to the U.S. may be required.

A program to monitor benefits to public health from the National Primary Drinking Water Regulations (microorganisms and chemicals) should be established. This could include data from Center for Disease Control and Prevention’s Emerging Infections Program and FoodNet active surveillance systems.
Multiple Barrier Control of Microbial Contaminants and Cost Benefit

Introduction
As the EPA formulates the national microbiological risk standards (see also section on public health, public perception, and stakeholders’ involvement), there are issues on source quality and protection, water treatment, distribution system and economic issues that must be integrated into the agency’s rationale for setting the microbial risk level in drinking water.

Essential Treatment and Economic Issues for Consideration

Two proposed essential issues that must be considered in the process of formulating a new microbial risk factor and standards are the effectiveness and affordability of multi-barrier control. Multi-barrier Control: There are three stages of microbiological contamination control. The EPA should consider the costs and control effectiveness of each of the following measures when determining the appropriate risk factor. Technology limitations should also be considered.

Source
- Source selection.
- Watershed and wellhead protection.

Treatment
- Removal – filtration
- Inactivation – Ozone, chlorination, chloramination, UV, ClO₂

Distribution System
- Prevent re-contamination – cross-connection control, water main sanitation, covered storage

Affordability. Cost as a percentage of other costs, (e.g., household costs) must be considered in the feasibility analysis. National averages should not be applied and local affordability issues should be the primary consideration. The workgroup expects that it would be difficult to determine what is locally affordable in every city or county. However, data compiled by the U.S. Bureau of Labor Statistics (http://www.bls.gov) into indexes such as cost-of-living index or consumer price index could be used in this application.

Important Treatment and Economic Issues for Consideration:

Performance Measures. It is EPA’s responsibility to develop microbiological monitoring and performance measures, (e.g., an improved surveillance program, improved microbiology measurement such as Polymerase Chain Reaction (PCR)) that can be used to track and demonstrate that improvements are working.

Unintended consequences. EPA needs to consider the impact of unintended consequences in cost (e.g., increased corrosion control) and in meeting other public health protection goals (e.g., disinfection byproducts).

Nonessential Treatment and Economic Issues for Consideration
Social Costs. Social cost per illness avoided should be part of the overall process. Methods to evaluate the social cost, including the QALY, need to be more fully developed. (See the recommendations under the public health section.)

Final guidance to the US EPA on the inclusion of the multi-barrier control and economic impact issues in the process of determining microbial risk level in drinking water

The EPA should allow water utilities the flexibility of meeting microbial goals through a combination of source control, treatment technologies, and distribution system controls as it is suggested in the following hypothetical example (Table II.).

Table II. Hypothetical example of several different treatment options for Cryptosporidium control.

CWA/SDWA Linkage. EPA needs to implement linkages between the Clean Water Act and Safe Drinking Water Act to ensure improved source control, which is what the US EPA Office of Science and Technology is currently considering.

Alternative Delivery Flexibility. EPA should provide maximum flexibility in allowing alternative delivery systems, e.g., point-of-use (POU) and point-of-entry (POE) systems and bottled water, to meet microbial control goals, especially for sensitive subpopulations and small systems.

Aesthetics. EPA ought to consider the impact of potential utility treatment choices and mitigation measures on aesthetic quality, e.g., taste and odor from higher chlorine levels. If there are aesthetic impacts, costs of addressing them should be included.

Public Perception and Stakeholder Involvement

Introduction

Studies suggest that much of the public would like to have “zero risk” tap water. Conversely, a recent national study (National Environmental Education & Training Foundation/Roper, 1999) suggests that a significant portion of the population lacks confidence in the safety of their tap water. In the study, three out of four adults expressed concern about the quality and safety of their drinking water, with more than one third saying they were “very concerned.” Almost a quarter of the people surveyed did not drink water straight from the tap because of aesthetic or health concerns. The current microbial risk standard of 1 infection in 10,000 people per year assumes that the current level of illness associated with microbials is acceptable to the general population. However, it is unclear whether much of the public is aware of the current microbial risk level or whether the current microbial risk level would be acceptable to the population if they were made aware of it.

The QALY metric may be a useful tool to help explain the risks and consequences of infection from microbials to the drinking water consumer. In addition, public perceptions and preferences may play a key role in evaluating the elements that go into a QALY calculation, as well as determining the acceptable range of QALYs.
Essential Public Perception and Stakeholders’ Input Issues for Consideration

It is essential that better information be developed concerning what the public currently knows about and expects from their water. Some data on these issues currently exist but are of varying quality and scope. Many studies have been conducted at the national level, yet we know that there is a great deal of variability even within regions. Moreover, the questions typically asked in such surveys do not often yield results that lead to specific policy recommendations. Some studies have also been conducted by specific water utilities, but many of these are considered to be proprietary information. Therefore, additional, in-depth studies that can yield more specific information are necessary. While the setting of microbial risk standard is fundamentally a public health issue, setting a standard that is unacceptable to large segments of the population will result in trust and credibility problems.

To develop effective risk communication strategies, communicators need to know the nature and extent of recipients’ knowledge of and beliefs about the pertinent issues if they are to design messages that will not be ignored, misinterpreted, or co-exist with misconceptions (Morgan et al., 1992; Clemen, 1991; Fischhoff et al., 1993). The primary scientific approach to learning about peoples’ beliefs and perceptions is through the “mental models” process (Altman et al., 1994; Bostrom et al., 1994). Mental models are webs of belief that people unconsciously use to guide how they learn, how they interpret information, and how they make decisions about topics that come to their attention. The models determine what people pay attention to and what they ignore. Mental modeling techniques involve lengthy, open-ended, one-on-one interviews using carefully designed questioning protocols, the intent of which is to encourage respondents to reveal whatever is on their minds using their own mode of expression. Respondents are asked to expand upon everything that they say, while the interviewer keeps track of the topics that have been addressed.

Because it is so extensive, the labor intensity of the mental modeling process precludes researchers from estimating the frequency of each belief in a population-based survey. Mental modeling can be used to capture the complexity of peoples’ feelings on specific issues. Following up with wide-ranging assessments, such as a structured questionnaire given to a large sample of the population, can then be used to attain statistically robust frequencies of pivotal beliefs that emerged from the mental modeling process. The results from this process give the communicator appropriate information to craft an effective risk communication plan.

Insights into people’s perceptions and related behaviors and choices help communicators to first identify the general public’s topics of concern and then enhance communication on those topics. An effective analysis can identify how different groups of people think about and respond to risk. Mental modeling has also been used extensively to evaluate communication strategies. Mental models can determine if a risk communication effort will actually reflect and affect lay people’s perceptions and concerns, not just what the experts such as government officials or utility managers think people need to know. Making erroneous assumptions about what the public perceives as important or problematic has sometimes resulted in ineffective and even damaging communication efforts.

Therefore, it is recommended that techniques such as mental modeling, focus groups, and expert panels be used on a regional basis to help identify key issues, public perceptions and concerns. The information yielded from mental modeling and other techniques can then be used in
regionally based telephone surveys to learn the extent of beliefs, attitudes, and intentions of the population concerning drinking water. Some existing, ongoing surveys such as FoodNet and the Behavioral Risk Factor Surveillance System may give a head start to this process. In addition to gaining a better understanding of the attitudes of the general population, getting the input of key stakeholders is also essential. Methods currently exist that can result in comprehensive stakeholder identification and input. Many of these have been well documented in the research literature and include techniques such as regional outreach meetings, the Internet, key informant interviews, and informal and formal hearings. EPA should recognize that funding is necessary to support travel and outreach to participants to assure the diversity of the stakeholder representation.

Such stakeholder groups should include but not be limited to the following:

- Representatives from industry, including those from the food, water, bottled water, medical treatment sectors
- Public health officials at the federal, state and local levels
- CDC, FDA, and medical advisors
- Consumers, including low income and sensitive subpopulations
- Academics and technical experts
- Representatives from the environmental community
- Wastewater industry professionals

Once the information and input derived from surveys of the public and stakeholders has been considered and the microbial risk level set, a risk-communication program must be designed to explain the rationale used. The EPA can lead this effort by providing tools (developed with the help of risk communication professionals) to those tasked with risk communication at the state and local level. In doing so, the EPA can help to ensure consistent communication messages across the country. This risk communication program should feature a method of evaluation (including pilot studies) before the communication efforts become widespread. Once the risk communication efforts are in place, a second wave of research to gauge their impact should be conducted.

**Final guidance to the US EPA on the inclusion of the public and stakeholders’ involvement in the process of determining microbial risk level in drinking water**

As knowledge of pathogens and methods of treatment and other technologies change, these issues should be revisited on a regular basis. Additional research may also be useful in response to newly discovered acute or chronic disease risks.

**Conclusions**

An expert workgroup proposed a process for determination of microbial drinking water standards that should be considered by the US EPA. In this process not only knowledge of epidemiology and water quality and treatment should be included. Issues such as treatment efficacy and affordability, social costs, public and stakeholders input, considerations of public concerns, knowledge and expectation were proposed to be integrated in the process. Based on these detail
issues a conceptual process for setting microbial drinking water standards was developed and recommended.
References

Figure I. Flow diagram of involvement by the US EPA and the water utilities in setting and meeting microbial standards.

<table>
<thead>
<tr>
<th>A water utility must consider the following To meet the treated drinking water standards for microbial contaminants:</th>
<th>The US EPA is responsible for consideration and research of the following issues:</th>
</tr>
</thead>
</table>
| **Source Water Protection Measures**  
  - Source Water Vulnerability  
  **Source Selection**  
  - Ground Water vs. Surface Water Supply  
    - Source Water Quality With Data  
    - Monitoring Programs  
  **Treatment Availability**  
  - Treatment Reliability  
    - Cost of Treatment  
    - Distribution System Water Quality | **Public Health Issues**  
  - Epidemiological studies  
  - Microbial measurement  
  - Waterborne disease  
  - Exposures types  
  - Severity of disease by specific organism  
  **Cost Benefit**  
  - Social cost per illness avoided  
  - Cost comparison  
  - Affordability and Effectiveness of Treatment  
  **Public Perception & Stakeholders Involvement**  
  - Public acceptance |

**Microbial risk level in treated drinking water:**

- Specific microbial concentrations in treated water.
- Decision by water utilities about treatment and source selection.
Figure II. The recommended process for determining microbial risk levels and standards for drinking water.

Utilities
Responsible for Multi-barrier Control

Source Water Selection, Protection
- groundwater
- surface water

Treatment
- chlorination
- ozonation
- filtration

Distribution & Water Quality Protection Programs
- flushing
- quality disinfection
- cross-connection control
- monitoring

Public Health Issues
- regulators
- public health agencies

Cost Benefit

Public Perception & Stakeholders Involvement

STEP 1 (concurrent)

STEP 2

STEP 3
Table I. Recommended issues to be considered by the US EPA in the process of microbial drinking water standards setting:

<table>
<thead>
<tr>
<th>Level of Importance</th>
<th>Public Health Issues</th>
<th>Multi-barrier Control and Cost Benefit</th>
<th>Public perception and Stakeholders Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential</td>
<td>- Identification of organisms</td>
<td>- Effectiveness of multi-barrier treatment (MBT)</td>
<td>- Identify key public issues, perceptions, concerns and expectations</td>
</tr>
<tr>
<td></td>
<td>- Characterization of diseases</td>
<td>- Affordability of MBT</td>
<td>- Identification and input of key stakeholders</td>
</tr>
<tr>
<td></td>
<td>- Determination of disease burden in a population</td>
<td>- Local affordability</td>
<td>- Development of risk communication programs</td>
</tr>
<tr>
<td></td>
<td>- Calculation of QALY&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Important</td>
<td>ND</td>
<td>- Development of monitoring and performance measures</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Unintended consequences in costs and new regulations</td>
<td></td>
</tr>
<tr>
<td>Nonessential</td>
<td>- Dose response for sensitive populations</td>
<td>- Social costs</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>- Chronic sequelae</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Determination of delayed responses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> – Quality Adjusted Life Years

ND – Not defined/considered by the workgroup
Table II. Hypothetical example of several different treatment options for *Cryptosporidium* control:

<table>
<thead>
<tr>
<th>Source Water Quality (oocysts/100L)</th>
<th>Source Control Measure</th>
<th>Treatment</th>
<th>Distribution System Control</th>
<th>=</th>
<th>Meeting Microbial Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>Protected Watershed</td>
<td>+ Chlorine Only</td>
<td>+ Comprehensive control program**</td>
<td>=</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>1 to 10</td>
<td>Protected Watershed</td>
<td>+ Ozone</td>
<td>+ Same</td>
<td>=</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>1 to 10</td>
<td>Minimal</td>
<td>+ Filtration + chlorine</td>
<td>+ Same</td>
<td>=</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>10 to 100</td>
<td>None feasible</td>
<td>+ Membrane</td>
<td>+ Same</td>
<td>=</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>&gt; 100</td>
<td>Moderate</td>
<td>+ Filtration + Ozone</td>
<td>+ Same</td>
<td>=</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

* Shaded areas indicate where utilities should have flexibility to meet microbial objectives.

** A comprehensive distribution system control program includes water main flushing, residual maintenance, cross-connection control, storage cleaning and disinfection and water main sanitation. The vigor of these program elements is an important consideration.

Note: Utilities should have the flexibility to chose from a “laundry” list of source control measures, such as owning the watershed, moving the intake, implementing best management practices, etc., and from a list of treatment alternatives, such as, ozone, UV, chlorine, filtration (conventional, direct), membranes, etc. as long as they can show that a proper level of treatment has been achieved.