Fact Sheet

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WCWC Walkerton Clean Water Centre
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CWAE Centre de Walkerton pour l'assainissement de l'eau
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Quantitative Microbial Risk Assessment: What, Why, How?

Key Words: Microbial Safety, QMRA, Health Canada's Model, Applications

Microbial Safety of Drinking Water

The microbial safety of drinking water is a top priority for a drinking water supply. The main risk to human health associated with drinking water consumption is drinking water that is contaminated with pathogenic bacteria, viruses, or protozoa. Drinking water should not be consumed before the microbial pathogens have been removed or inactivated to a safe level.

To confirm the microbial safety of drinking water, indicator microbial parameters (such as *E. coli*, and total coliforms) are monitored and investigation is required when the level of microbial detection exceeds the federal or provincial standards. These parameters should be used as part of a multi-barrier approach to producing safe drinking water, as there are limitations associated with using only a reactive approach (i.e. corrective actions triggered by end-product testing). First, microbiological sample analysis takes time. This means that many people may have already been exposed before the sampling results are available. Second, samples are limited to be analyzed for indicator organisms at a prescribed sample volume, number and frequency.

Therefore, instead of traditional reactive approaches, water utilities should consider a preventive multi-barrier approach to ensuring safe drinking water. Such an approach emphasizes the design of robust systems and promotes source to tap strategies (CCME, 2004). A multi-barrier approach utilizes multiple systems working together to ensure the safety of drinking water. Such barriers include source water protection, proper selection and operation of treatment systems, management of distribution systems to maintain treated water quality, routine monitoring for verification of drinking water quality, use of qualified personnel and communication and public education.

Risk assessment is part of this preventive approach, including Quantitative Microbial Risk Assessment (QMRA). QMRA is becoming popular as a method to estimate the microbial risk associated with a drinking water system, providing a scientific basis for risk management decisions.

What is QMRA?

QMRA is a method that can be used to estimate the health risk associated with drinking water consumption. According to Health Canada's definition, "QMRA uses source water quality data, treatment barrier information and pathogen-specific characteristics to estimate the burden of disease associated with exposure to pathogenic microorganisms in a drinking water source" (Health Canada, 2011)

As a risk-based approach, QMRA can be used to assess existing water treatment

systems, using site-specific water quality data, to determine the need for additional treatment barriers, and to evaluate the impact of source water quality to the overall risk (Health Canada, 2011).

Health Target: How Safe is Safe Enough?

Obviously, increasing the level of treatment can reduce the microbial risk. A higher level of safety can be reached by including additional control measures or more advanced treatment technologies, by setting stricter limits, or by more intensive monitoring. The question is how do we ensure that these investments actually result in meaningful public health improvements? It is important to remember that drinking water is not the only route of exposure to contaminants, and limited resources have to be split in a reasonable manner between drinking water, recreational water, food, air, and other possible exposure routes. The health risks of the water supply must be carefully considered so that investments are made where they will have the most impact on protecting public health.

Risk free is not a realistic or achievable target, therefore, a meaningful question is: How safe is 'safe enough'? What is the risk level that is both tolerable and achievable with reasonable costs? By setting health-based targets, it becomes clear when drinking water is reasonably safe. For example, the Dutch Drinking Water Act (Schijven et al., 2011) requires QMRA to be applied to evaluate water treatment systems to meet a health-based target: a risk of less than one infection per 10,000 individuals (1/10,000 = 0.0001 = 10^{-4}) per year. This means that if 10,000 people each consume an average of 1 L per day of unboiled tap water, one individual may be infected by a waterborne pathogen.

Microbial risk can also be expressed as a risk of illness, which is usually a percentage of the risk of infection. For example, 70% of people develop illness after infection by *Cryptosporidium* (Health Canada, 2012). However, the severity of illness caused by microbial infection in humans varies depending on factors such as age and physical condition. Therefore, the World Health Organization (WHO) has developed the disability adjusted life year (DALY) as a common unit of risk to express health outcomes in terms of the human impact. WHO (2011) established a risk endpoint (Disease Burden) of 10^{-6} DALY per person per year as a health target. This target has been adopted in the Canadian Drinking Water Guidelines for enteric pathogens (Health Canada, 2011).

How to Understand DALY

Although risk of infection, risk of illness, and DALYs, can all be used as endpoints for risk assessment, DALYs are preferred because it considers both the probability of experiencing an illness, injury or even death, and the impact of the associated health effect. DALY is used to provide a single number to capture all of the health costs caused by the illness. One DALY can be thought of as one lost year of "healthy" life. Therefore, the WHO target (and Canadian Guideline) of 10^{-6} DALY is equivalent to approximately 32 seconds loss of "healthy" life per person per year.

To convert risk of illness to DALY, a "disease burden" is calculated for each pathogen. For example, the disease burden (including all health outcomes) for *Giardia* is calculated as 0.0017 DALY/case of illness (Health Canada, 2012). This is to say, on average, each case of *Giardia*-causing illness can cause a loss of 15 hours of "healthy" life, considering the fact that the outcome of a *Giardia* illness can vary from mild to severe diarrhea and very rarely, even death. The Health Burden for *Cryptosporidium* is

considered the same as *Giardia*. Detailed explanations and calculations can be found in the Health Canada technical document (Health Canada, 2012).

Introduction of Health Canada's QMRA model

Health Canada's QMRA model was initially developed in 2007 and recently updated in 2011. It is a tool to carry out site specific investigations to help users understand the microbiological risks in a drinking water system. This model uses Microsoft Excel.

Information on raw water quality (i.e. pathogen concentrations) and treatment performance (i.e. pathogen removal information and disinfection conditions) are needed as model inputs. It is not practical to use pathogen concentrations from the finished water directly. This is because there should be extremely low concentrations of microorganisms in finished drinking water, which makes direct monitoring almost impossible. To detect a single pathogen, a huge amount of water would have to be filtered, which is both costly and impractical.

This tool includes five reference pathogens, including *Cryptosporidium parvum*, *Giardia lamblia*, Rotavirus, *E.coli* O157:H7, and *Campylobacter*. Four filtration methods, rapid granular filtration (with or without coagulation/sedimentation), slow sand filtration, microfiltration and ultrafiltration, are included in the model, as well as five disinfection methods (chlorine, chloramine, ozone, chlorine dioxide, ultraviolet light (UV)).

Users can enter the site-specific pathogen concentrations from their raw water, and choose the types of treatment used in their systems. The log removal values for the filtration processes are based on literature values. Alternatively, users have the option to enter the specified removal credit based on their own data. For chemical disinfection, the user enters the conditions for their treatment system (i.e. residual concentration, contact time, temperature and pH). For UV, the user enters the UV dose. The log inactivation is calculated using published inactivation kinetics. The Excel model processes all the calculations, reports all the results, and shows comparisons in figures. Case studies can be found in Health Canada's technical guideline documents (2011, 2012).

This model provides a comparative estimate of the level of risk from different pathogens, which gives users a better understanding of what drives the risk in their system, and where they may best target efforts to address those risks. If the outcome of the assessment indicates that the drinking water could be unsafe under some conditions (e.g. extreme events), QMRA can help identify effective measures that can be implemented to reduce the risk below health-based targets.

Reference

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For More Information

For further information and resources on drinking water research and water operator training programs, please visit our website: www.wcwc.ca

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