Quantitative Microbial Risk Assessment (QMRA)

**Research Document - September 2025**

# Executive Summary

This document provides a comprehensive overview of Quantitative Microbial Risk Assessment (QMRA) methodology, its applications in New Zealand context, and current research developments. QMRA is a systematic approach to estimating the risk of infection, illness, or death resulting from exposure to pathogenic microorganisms in water, food, and environmental sources.

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# 1. Introduction to QMRA

Quantitative Microbial Risk Assessment (QMRA) is a scientific framework used to estimate the risk of adverse health effects from exposure to pathogenic microorganisms. It integrates information from various disciplines including microbiology, epidemiology, environmental science, and public health.

## 1.1 Key Components

* Hazard Identification: Identifying pathogenic microorganisms of concern
* Exposure Assessment: Estimating the magnitude, frequency, and duration of exposure
* Dose-Response Assessment: Characterizing the relationship between dose and health effects
* Risk Characterization: Integrating exposure and dose-response to estimate risk

# 2. QMRA Framework and Methodology

The QMRA framework follows a systematic approach aligned with international guidelines including WHO Water Safety Plans and Codex Alimentarius food safety principles.

## 2.1 Mathematical Models

QMRA employs various mathematical models to quantify risk:

* Exponential model: P(inf) = 1 - exp(-r × dose)
* Beta-Poisson model: P(inf) = 1 - (1 + dose/β)^(-α)
* Monte Carlo simulation for uncertainty analysis
* Bayesian approaches for parameter estimation

# 3. New Zealand Regulatory Context

New Zealand has established comprehensive regulatory frameworks for microbial risk management in water and food systems.

## 3.1 Key Regulatory Bodies

* Taumata Arowai - Water Services Regulator
* Ministry of Health - Public Health Guidelines
* Ministry for Primary Industries (MPI) - Food Safety
* Regional Councils - Environmental Management

## 3.2 Drinking Water Standards

The Drinking Water Standards for New Zealand (DWSNZ) specify maximum acceptable values for microbiological determinands including:

* E. coli: <1 per 100 mL
* Total coliforms: Monitored as process indicator
* Protozoa: 3-log removal/inactivation requirement
* Viruses: 4-log removal/inactivation requirement

# 4. Water Quality Risk Assessment

Water quality risk assessment is critical for ensuring safe drinking water supply and protecting public health from waterborne pathogens.

## 4.1 Priority Pathogens

* Bacteria: Campylobacter, Salmonella, pathogenic E. coli, Legionella
* Viruses: Norovirus, Rotavirus, Adenovirus, Hepatitis A
* Protozoa: Cryptosporidium, Giardia, Naegleria fowleri
* Cyanobacteria and associated toxins

## 4.2 Source Water Protection

Implementing multiple barriers from catchment to consumer:

* Catchment management and source protection zones
* Treatment processes (coagulation, filtration, disinfection)
* Distribution system integrity
* Monitoring and verification programs

# 5. Food Safety Applications

QMRA is extensively used in food safety to assess risks throughout the food chain from production to consumption.

## 5.1 Food Production Systems

* Primary production (farms, aquaculture)
* Processing and manufacturing
* Distribution and retail
* Food service and consumer handling

## 5.2 Critical Control Points

Hazard Analysis and Critical Control Points (HACCP) integration with QMRA:

* Temperature control (cooking, cooling, storage)
* pH and water activity management
* Cross-contamination prevention
* Time limits for pathogen growth

# 6. Environmental Health Considerations

Environmental factors significantly influence microbial risk in both natural and built environments.

## 6.1 Climate Change Impacts

* Increased water temperature affecting pathogen survival
* Extreme weather events and flooding risks
* Changes in precipitation patterns affecting water sources
* Sea level rise and saltwater intrusion

## 6.2 Recreational Water Quality

Managing microbial risks in recreational waters including beaches, rivers, and lakes through monitoring and public advisories.

# 7. Case Studies

## 7.1 Havelock North Water Crisis (2016)

The Havelock North campylobacteriosis outbreak affected over 5,000 people and highlighted the importance of source water protection, treatment barriers, and proactive risk assessment. Key lessons learned include the need for mandatory treatment of all drinking water supplies and improved regulatory oversight.

## 7.2 New Zealand Shellfish QMRA

Development of risk-based management strategies for shellfish harvesting areas considering norovirus and bacterial contamination from wastewater discharges and agricultural runoff.

# 8. Future Research Directions

* Integration of genomic techniques for pathogen detection and characterization
* Machine learning applications in risk prediction
* Climate change adaptation strategies
* One Health approaches linking human, animal, and environmental health
* Real-time monitoring and early warning systems
* Community-specific risk assessment tools

# 9. References and Resources

## Key Publications

* WHO (2016) Quantitative Microbial Risk Assessment: Application for Water Safety Management
* Haas, C.N., Rose, J.B., & Gerba, C.P. (2014) Quantitative Microbial Risk Assessment, 2nd Edition
* Taumata Arowai (2022) Drinking Water Quality Assurance Rules
* Ministry of Health (2018) Drinking Water Standards for New Zealand
* MPI (2021) Microbiological Reference Criteria for Food

## Useful Websites

* Taumata Arowai: www.taumataarowai.govt.nz
* Ministry of Health: www.health.govt.nz
* MPI Food Safety: www.mpi.govt.nz/food-safety
* ESR Public Health: www.esr.cri.nz
* Water New Zealand: www.waternz.org.nz

# Appendix A: Glossary of Terms

**QMRA:** Quantitative Microbial Risk Assessment

**DALYs:** Disability Adjusted Life Years

**Log Reduction:** Logarithmic reduction in pathogen concentration

**MPN:** Most Probable Number

**CFU:** Colony Forming Units

**HACCP:** Hazard Analysis and Critical Control Points

**WSP:** Water Safety Plan

# Appendix B: Common Dose-Response Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Pathogen | Model | Parameters | Reference |
| Campylobacter jejuni | Beta-Poisson | α=0.145, β=7.59 | Teunis et al. 2005 |
| Cryptosporidium parvum | Exponential | r=0.0042 | Haas et al. 1996 |
| Rotavirus | Beta-Poisson | α=0.253, β=0.42 | Regli et al. 1991 |
| E. coli O157:H7 | Beta-Poisson | α=0.49, β=1.81×10^5 | Strachan et al. 2005 |

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