Food and Waterborne Parasitology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Food and Waterborne Parasitology

journal homepage: www.elsevier.com/locate/fawpar

Risk-based management of drinking water safety in Australia: Implementation of health based targets to determine water treatment requirements and identification of pathogen surrogates for validation of conventional filtration

Paul Monis*, Melody Lau, Martin Harris, David Cook, Mary Drikas

Australian Water Quality Centre, South Australian Water Corporation, GPO Box 1751, Adelaide, SA 5001, Australia

ARTICLE INFO

Keywords:
Cryptosporidium
Surrogate
HBT
Water
Conventional filtration

ABSTRACT

The safety of drinking water in Australia is ensured using a risk management framework embedded within the Australian Drinking Water Guidelines (ADWG). This framework includes elements for hazard identification, risk assessment, risk mitigation, verification of barrier performance and monitoring for any changes to the hazards that influence source water quality. The next revision of the ADWG will incorporate Health-Based Targets (HBTs) for achieving microbiologically safe drinking water. This incorporates Quantitative Microbial Risk Assessment and the metric of Disability Adjusted Life Year (DALY) to define safety, with a target of 1×10^{-6} Disability Adjusted Life Year (1 microDALY) set as the maximum tolerable disease burden from drinking water, which in the case of *Cryptosporidium* is $< 1.3 \times 10^{-5}$ oocysts/L. The resulting product water specification, in combination with knowledge of pathogen challenges in source waters, allows the determination of the treatment requirements to ensure public safety. The ADWG revision provides default removal values for *Cryptosporidium* for particular treatment processes, such as conventional coagulation and dual media filtration. However, these values are based on assumptions regarding treatment plant design, operation and water quality. To properly manage risk and demonstrate compliance with the guidelines, water utilities may need to validate treatment performance for *Cryptosporidium* removal. A particular limitation is the absence of *Cryptosporidium* surrogates for full-scale filter validation. This paper will provide an overview of risk-based management of drinking water safety in Australia, the development of health-based targets for microbial pathogens and the evaluation of *Cryptosporidium* surrogates for conventional coagulation and dual media filtration.

1. Introduction

1.1. Approaches for managing drinking water quality

The World Health Organisation (WHO) has identified access to safe drinking water as a basic human right (WHO, 2011). In combination with adequate sanitation and hygiene, safe drinking water provides significant health benefits to the community, improving quality of life and reducing the social and economic burden of disease (WHO, 2011). Achievement of these goals varies across

* Corresponding author.
E-mail address: paul.monis@sawater.com.au (P. Monis).

http://dx.doi.org/10.1016/j.fawpar.2017.08.002
Received 3 July 2017; Received in revised form 18 August 2017; Accepted 21 August 2017

the world, with local success influenced by a variety of environmental, economic, social and geopolitical factors. Different approaches can be used to ensure the safety of drinking water. The WHO provides a risk-based framework for managing the safety of drinking water. This framework has key components: using public health outcomes to define tolerable levels of contaminants in drinking water (health-based targets); the use of water safety plans incorporating hazard identification and control measures, monitoring of processes or barrier performance; implementation of management systems including documentation and communication; and review and audit of water safety plans (WHO, 2011). The WHO drinking water guidelines are comprehensive, also providing information regarding contaminants (microbial, chemical and radiological including guidance values), treatment options, disinfection and analytical methods (WHO, 2011).

In the United States of America (USA), drinking water safety is federally legislated through the Safe Drinking Water Act, which allows the United States Environmental Protection Agency to implement the provisions within the act and to regulate the quality of drinking water to protect public health. The approach used in the USA is prescriptive, with the National Primary Drinking Water Regulations used to define maximum contaminant loads or treatment requirements to provide legal protection of public health from drinking water contaminants (USEPA, 2013). These regulations are further supported by rules that mandate treatment techniques and/or monitoring requirements for chemical or microbial contaminants. For example, the Long Term 2 Enhanced Surface Water Treatment Rule prescribes the analytical methods and treatment requirements to protect public water supplies from contamination by the enteric pathogen *Cryptosporidium* (USEPA, 2006).

The methodology used to manage the safety of drinking water in Australia uses the same philosophy as the WHO guidelines, providing a risk management framework rather than prescribing monitoring requirements, analytical methodologies or treatment processes for meeting regulated water quality targets. The Australian Drinking Water Guidelines (ADWG) incorporates aspects from standards for quality systems (ISO 9001), risk management (AS/NZS 4360:2004) and the management of food safety (hazard analysis and critical control points (HACCP)). The ADWG recognises the amount and complexity of the information presented and so it clearly articulates the fundamental guiding principles (such as “The greatest risks to consumers of drinking water are pathogenic microorganisms. Protection of water sources and treatment are of paramount importance and must never be compromised.”) and the structure of the framework for the management of drinking water quality (NHMRC, 2016b). The management framework endorsed by the ADWG has 12 elements, broadly grouped as a commitment to drinking water quality management, systems analysis and management (effectively the HACCP component of the framework), supporting requirements (including elements of quality systems such as staff training, document control) and review (NHMRC, 2016b). There is no Australian federal legislation covering drinking water safety and the ADWG is a guideline for best practice, rather than a standard, so by itself is not enforceable. Instead, the Australian states and territories separately legislate to ensure drinking water safety, typically via acts or regulations that specify, among other licensing requirements, that water suppliers must comply with the ADWG.

1.2. Health-based targets for managing contaminants in water

One approach to managing contaminants present in drinking water sources is the application of health-based targets (HBTs). The WHO describes four types of health-based targets: health outcome targets, water quality targets, performance targets, and specified technology targets (WHO, 2011). These targets are used in combination to achieve safe drinking water. Health outcome targets are defined using concepts such as tolerable disease burden (less than a particular frequency of disease from drinking water) in the case of microbiological contaminants, or no adverse health effects in the case of chemical or radiological contaminants. Provided that sufficient toxicological data are available, the derivation of no adverse effect levels for chemicals is relatively straightforward. There are different approaches to defining tolerable disease burden; in the USA this is based on the frequency of a particular disease occurring, whereas the WHO also incorporates disease severity to calculate disability-adjusted life years (DALY), which is effectively the average decrease in life expectancy as a consequence of a person contracting a particular disease. Water quality targets are guideline values that are applied to drinking water to meet health outcome targets. These are generally only used for chemicals, since the guideline values for most chemicals are usually at levels that can be readily measured. In contrast, it is neither practical nor technically possible to measure the extremely low levels of microbial contaminants required to demonstrate compliance with health outcome targets. Instead, performance targets are used to define the amount of source water treatment required to reduce the number of pathogens in drinking water so that the health outcome target is not exceeded. These performance targets can be achieved using specified technologies, which have been validated to remove particular contaminants of concern.

In Australia, the ADWG provides guideline values for chemical contaminants but not for microbial contaminants. The draft revision of the ADWG incorporates microbial HBTs and was released for public comment in 2016 (NHMRC, 2016a). This revision uses 1 micro DALY as the health outcome target for waterborne pathogens, describes the use of *Escherichia coli* or specific pathogen monitoring data for risk-based categorisation of water sources, suggests minimum treatment targets ($\log_{10}$ removal values (LRV)) for protozoa (*Cryptosporidium*), bacteria, and viruses for each risk category, and provides default LRV treatment credits for commonly used treatment processes (NHMRC, 2016a). The draft microbial HBT framework also makes provision for the validation of treatment processes that do not have well established published LRVs or for when credit is sought for a process above the default LRV specified in the framework.

1.3. Significance and management of Cryptosporidium in water

The enteric pathogenic protozoan *Cryptosporidium*, which has a low infectious dose, limited options for effective drug treatment, and resistance to the levels of chlorine used for disinfecting drinking water (Fayer, 2004), is recognised as a high risk to public health