

INCREASING THE TRANSPARENCY OF WATER QUALITY MANAGEMENT

Health-based targets offer opportunity to improve
insights on drinking water safety

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ABSTRACT

Insights offered to the public on the microbial safety of water are commonly focussed on verification monitoring results, particularly an observed absence of specific pathogenic and indicator organisms. The results of such verification monitoring are available after the water sampled has passed into the distribution system. In the case of drinking water supplies this may erroneously imply that operational response is solely made on the basis of lagging indicators. This is not of benefit to the consumer or the utility.

An opportunity for connecting public health theory to drinking water supply practise is offered by the introduction of health-based targets. This paper describes a method to leverage this opportunity to allow the public transparent and accurate insights into drinking water safety.

The method involves: confirming source risk and commensurate treatment requirements; formalising treatment requirements under a Hazard Analysis and Critical Control Point (HACCP) or similar approach; assembling HACCP performance data for internal organisational reporting; and finally, establishing organisational and stakeholder acceptance for enabling these data and the processes they describe to form the basis of refocussed consumer confidence reporting.

This method was implemented by Sydney Water. An internet-based daily report was established, demonstrating the performance of the filtration,

primary and secondary chlorination, and fluoridation processes against national guidelines and the achievement of the 10^{-6} Disability-Adjusted Life Years per person per year health outcome target.

INTRODUCTION

The safety of drinking water is primarily achieved through successful catchment management and treatment, including filtration or disinfection or both, with the type and extent of treatment required being commensurate to the untreated water risk.

This is known as the 'multiple-barrier' approach to drinking water safety (National Health and Medical Research Council [NHMRC] & National Resource Management Ministerial Council [NRMCC] 2011).

In contrast, it is intuitive to judge the safety of drinking water based principally on an observed absence of contamination. This was the case at the birth of modern drinking water quality management.

John Snow (the British physician and founder of modern epidemiology) remarked on his examination of the Broad Street pump during a substantial cholera outbreak in 1855, Soho, London, "on examining the water ... I found so little impurity in it of an organic nature, that I hesitated to come to a conclusion" (cited in Parkes 2013, p. 1547). To an extent this is mirrored in modern times by water utilities typically focusing the public communication of drinking water safety on verification monitoring results.

The context of treatment and the multiple-barrier approach is not necessarily (or usually) included in the discourse.

A notable example of the ever-increasing scientific and engineering rigour underpinning water treatment and the multiple-barrier approach is the health-based target (HBT) concept, which is now widely recognised as a model to measure the safety of drinking water. An HBT of 10^{-6} Disability-Adjusted Life Years per person per year (1 μ DALY/person/year) for drinking water quality was primarily identified by the World Health Organization (2011), and will soon be adopted in Australian guidelines (NHMRC, 2016).

Water treatment performance criteria have been calculated for the achievement of this target (Water Services Association of Australia [WSAA], 2015). Criteria include log-reduction values commensurate with the assessed catchment risk, with associated performance targets for treatment processes defined.

The HBT concept supports the interpretation of drinking water safety as existing along a 'continuum' of water treatment log removal (Walker 2016). The continuum characterises shortfalls in meeting the 1 μ DALY/person/year outcome as indicative of the extent and urgency of required improvement. It is also a way for operators (and others in the industry) to appreciate public health outcomes achieved in the unavoidable absence of sufficiently sensitive surveillance.

This paper identifies principles for increasing the salience of drinking water treatment by publishing associated performance data. The approach is incremental: a need to systematise HBT-related treatment criteria and achieve acceptability of associated public reporting within the utility is essential.

METHOD

Assess Source Water Risks and Identify Treatment Criteria

Source water risk was assessed and treatment criteria were identified through the method set out by WSAA (2015). The method is adapted to the Australian context and is specific to achieving the 1 μ DALY/person/year health outcome target. The 'two-tiered' option was selected, involving a vulnerability assessment and quantitative microbial risk assessment (QMRA). The vulnerability assessment involved comparing a catchment sanitary survey to indicator *Escherichia coli* counts. *Cryptosporidium* spp. was used as the QMRA reference pathogen due to it representing a limiting factor in the treatment of chlorine-



resistant pathogens and due to the availability of around 10 years' historical source water monitoring data. With one exception, the vulnerability assessment and the QMRA for each supply was performed by the source water supplier. Assessment of one run-of-river supply which is not the responsibility of the source water supply organisation was performed by Sydney Water.

This arrangement was needed due to the drinking water supply system being vertically disaggregated, with Sydney Water responsible for water treatment and distribution, and a separate source water supply organisation managing the majority of the region's catchments and source water storages. The two organisations' assessments were reviewed for validity and concordance. Results of the 'tier one' and 'tier two' assessments were expressed in terms of log-reduction values required by specific treatment processes and translated to treatment process critical limits.

Treatment performance data for each water treatment plant were compared to the relevant treatment process critical limits appropriate to deal with the rated catchment condition. If found, any shortfall in pathogen removal would have triggered the development of an associated improvement initiative in line with the twelfth 'element' of the 'Framework for management of drinking water quality' (ADWG Framework) (NHMRC & NRMCC 2011).

Embed the Treatment Criteria Into a Quality Management System

The ongoing achievement of the 1 μ DALY/person/year outcome was assured through the implementation of the related treatment criteria in the utility's water quality management system. The identified treatment criteria were formalised in the 'drinking water specification' under the existing 'specifier—provider' organisational operating model.

The specification translates the diverse customer, business, regulatory and formal requirements into explicit treatment criteria, including those criteria for achieving the HBT. The treatment processes and limits identified in the previous step were set as the specification's critical control points (CCP) and critical limits, respectively. Operational limits for aesthetics, supply continuity, and system integrity were also set.

Assemble the Related Operational Monitoring Data and Use These for Internal and Public Reporting

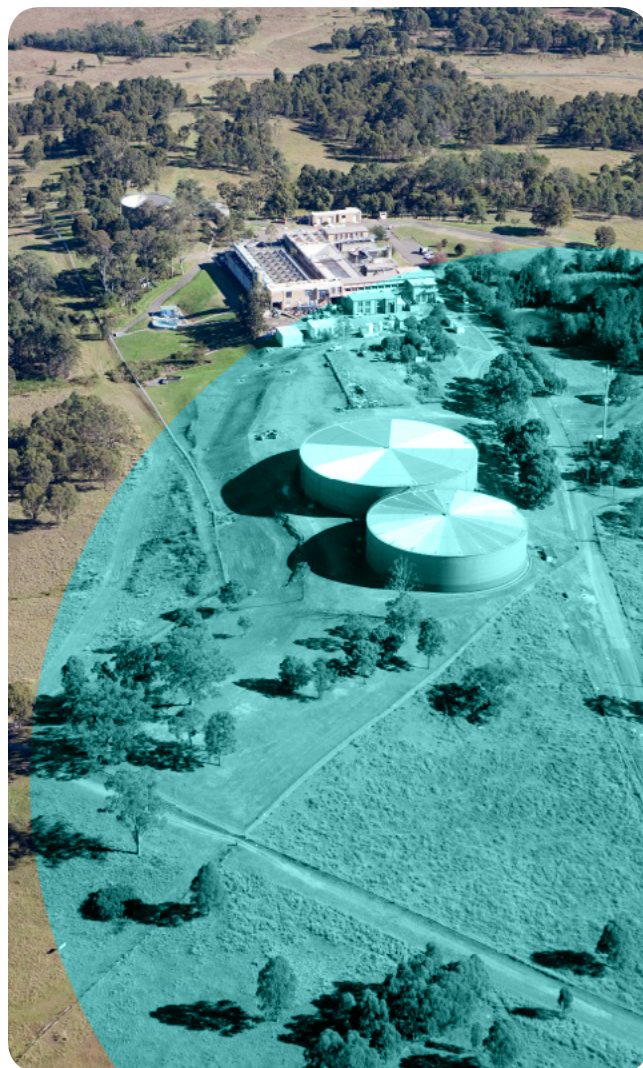
In preparation for the change to reporting, a full review of the existing drinking water quality monitoring program was performed. A program was developed to align monitoring with the drinking water specification, in addition to established industry requirements, guidance, and practise.

A new internal report demonstrating performance against the drinking water specification was prepared by the relevant treatment and network operators. In line with WSAA (2015) guidance, this report was used as the 'single source of truth' for the organisation's internal oversight of drinking water quality performance. A proofing period of around 18 months was used to develop and implement appropriate algorithms to treat the typically 'noisy' SCADA data.

When preparing to launch the public version of the report, the entire drinking water quality section of the organisation's website was redesigned using

information technology user experience principles. Business and user needs were separately identified, and the development of the pages was focussed on meeting both. Appropriate and understandable ways to communicate technical concepts were examined, including the 'Swiss cheese' analogy for the multiple-barrier approach (Wu et al. 2009). Website search data were reviewed in order to confirm the key areas of customer interest. All new webpages were made to be 'responsive', meaning the content is rendered in a manner which adapts to and optimises for functionalities offered by mobile devices.

Possible answers to foreseeable questions such as "why not aim for zero μ DALY" were considered, as was the extent that the HBT concept was expressly reflected in the new report.



RESULTS

The 'tier one' and 'tier two' assessments confirmed that the 1 μ DALY/person/year target was achieved by each of the nine water treatment plants in the greater Sydney region.

The characteristics published in the new daily drinking water quality report (Figure 1) were those associated with national treatment guidelines as well as the achievement of 1 μ DALY/person/year (Table 1).

The performance of the secondary disinfection and fluoridation processes against national guidelines was also included. According to website search data (not shown), customers' interests primarily lay in whether the region's drinking water was safe to drink. Accordingly, the Sydney Water main webpage for water quality was reworked, with a summarised explanation of how drinking water safety is achieved with the multiple-barrier approach.

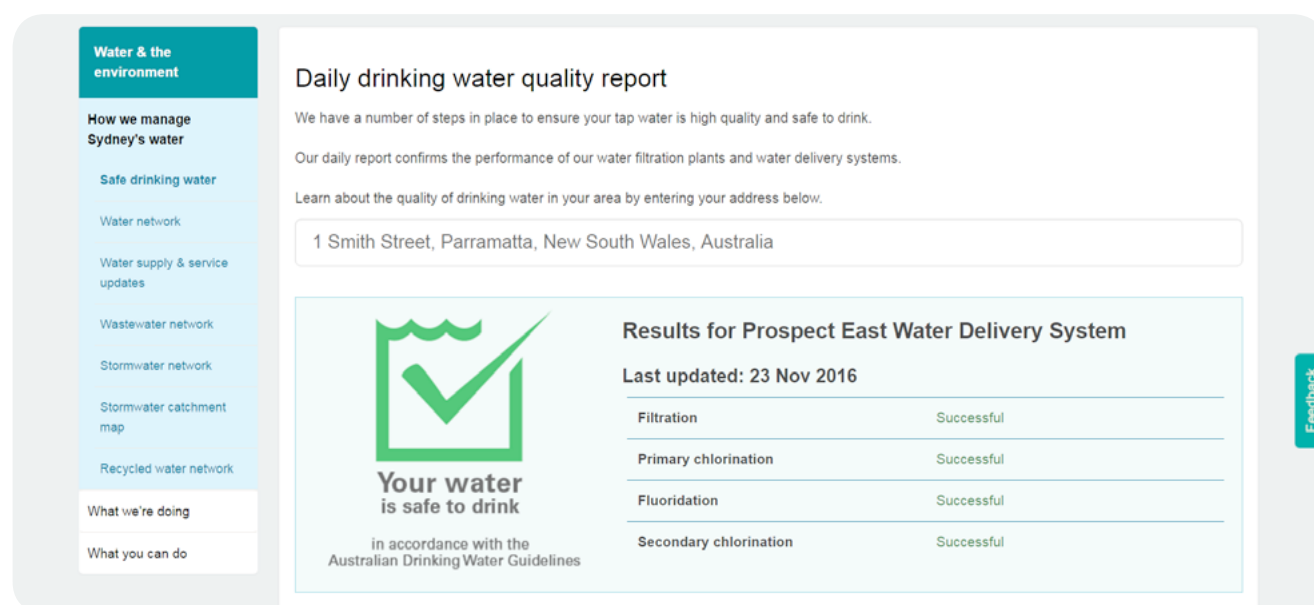


Figure 1 - Excerpt of the Sydney Water daily drinking water quality report demonstrating achievement of critical limits set under national guidelines, including those linked to health-based targets

TABLE 1: Constitution and derivation of the new daily drinking water quality report

Reported critical control point	Critical limit	Derivation of critical limit
Individual filter effluent turbidity	> 0.5 Nephelometric Turbidity Units (reportable to public if > 15 minutes)	Australian Drinking Water Guidelines treatment requirements and quantitative microbial risk assessment based on 1 μ DALY/person/year
Primary chlorination	< 0.5 mg/L for > 30 minutes	
Fluoridation	> 1.5 mg/L	Australian Drinking Water Guidelines health-related guideline value and state regulatory limit
Secondary chlorination	> 5 mg/L (as chlorine)	Australian Drinking Water Guidelines health-related guideline value

This page was constructed to act as an index for the possible user journeys identified during the user experience workshops. A page satisfying the needs of each major type of user journey was then created.

These included: the 'Daily drinking water quality report' page for those requiring further detail to be satisfied of drinking water safety; the 'Water analysis' page for those needing a specific verification monitoring result, for say, a niche industry or use; 'Facts about drinking water' for those having commonly asked questions; and 'Our drinking water management system' for those who require information on the regulatory basis of drinking water quality assurance.

Explanatory content was developed for the 'Daily drinking water quality report' page due to the relative novelty of the characteristics reported.

DISCUSSION

Major Australian water utilities typically implement a form of water quality management system guided by the ADWG Framework, HACCP, or the ISO 22000 standard. Each of these include reporting to senior management as an important factor contributing to the overall assurance of water quality, and each includes the CCP or similar concept. The approach described in this paper recognises the benefit of publicly reporting on the quality of drinking water in the form used internally by Sydney Water to monitor its safety for public consumption. Implementation

of the approach requires careful planning and an investment of time and effort. Three key issues worthy of discussion were encountered during implementation.

First, there is a need to create algorithms for the treatment of operational data. These data are typically managed through systems such as Supervisory Control and Data Acquisition (SCADA), with implementation of these technologies differing from one utility to the next. The data may not be immediately suitable for use in reporting, and therefore appropriate, defensible algorithms for treating the data may be needed. Such algorithms should deal with situations including where faulty signals are recorded and where processes were offline or the data are otherwise not representative of water supplied to customers.

Second, there is a need to achieve acceptance of the approach broadly across the water utility. The approach inherently provides a greater focus on operational performance, though a challenge may lie in the political and managerial acceptability of increased scrutiny. It is arguable that any such resistance is an artefact of the existing, incorrect paradigm of the perceived definitiveness of verification monitoring results. An incremental approach with the introduction of internal CCP reporting from operator to Executive Board (in which time any data validity issues may be addressed) is important for the eventual broad acceptance for publication. As supported by the water safety continuum concept (Walker, 2016), it is important and appropriate that non-compliance with the 1 μ DALY/person/year target be considered as a trigger for improvement planning and not necessarily as a failure.

Third, the water industry should continue to consider the approach for communicating the health-based target concept. A commonly-used method for science communication involves the use of analogy and comparison, but an acceptable outcome was not achieved with this method in this case. To potentially put health-based targets into perspective for consumers (when introduced), select risk factors attributable to the burden of disease in Australia in 2011 identified by the Australian Institute of Health and Welfare (2016) were compared to the microbial HBT for drinking water (Supplement 1). However, as the public health discipline involves language and measures which may be confronting for those unfamiliar to it, the link between treatment performance and health outcomes was not described in the new public report.

The benefits associated with focussing public reporting on treatment operation performance are numerous. Focussing consumer confidence reporting on critical control processes increases the importance of what is reported. Events known to be related to public health outcome are highlighted, and conversely, results not as strongly associated with public health outcome do not need to be included.

This is relevant for Sydney Water, which has published analytical results for *Cryptosporidium* spp. oocyst and *Giardia* spp. cyst counts in finished water for many years. The underlying analyses are limited by factors (including infectivity, viability, strain, and source), which must be taken into account when considering a related public health outcome but are difficult to confirm with certainty (Wohlsen & Katouli 2008).

This places an onus on Sydney Water and its health regulator to explain and respond to data which are known to be poorly correlated to public health consequence. This and similar situations are dispensable when information confirming achievement of public health-related objectives is central to consumer confidence reporting. The internal focus on the water utility's operations are also improved. Scrutiny offered by the publication of operational results highlights the role of the underlying HACCP system. This can be expected to improve engagement in drinking water quality management planning, and focus improvement planning and investment toward the HACCP system.

CONCLUSION

The implementation of the microbial HBT provides an opportunity to increase the importance and relevance of consumer confidence reporting. The associated measures may not be immediately intuitive, but by their nature are a powerfully transparent and accurate characterisation of whether and how the safety of drinking water is, in practice, assured.

ACKNOWLEDGEMENTS

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SUPPLEMENT 1

A selection of attributable risk factors for the burden of disease and injury in Australia in 2011 (Australian Institute of Health and Welfare 2016) were compared to the targeted microbial health outcome for drinking water (Figure S1). This involved the conversion of the microbial health-based target for drinking water (10^{-6} Disability-Adjusted Life Years per person per year) to a population measure rather than per-person, using a 2011 population estimate for Australia (Australian Bureau of Statistics 2012).

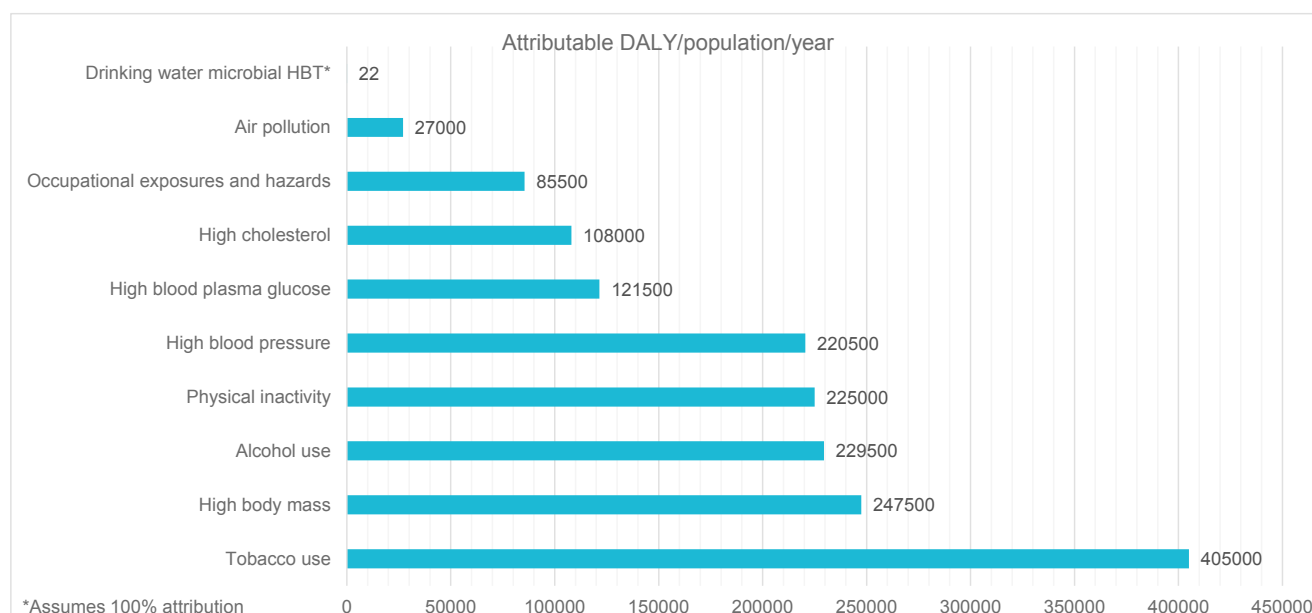


Figure S1 - Select attributable risk factors for the burden of disease and injury in Australia in 2011 (Australian Institute of Health and Welfare 2016) compared to the targeted microbial health outcome for drinking water.

The comparison should be interpreted with care as it assumes 100% of the microbial risk involved in drinking water would be attributable to health outcomes, which is not possible due to limitations in public health surveillance. Similar limitations are already reflected in the other risk factors presented. Despite the comparison demonstrating the stringency of the HBT, it is likely an overestimation of the microbial risk of drinking water relative to the other factors presented.

SUPPLEMENT REFERENCES

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