MAKING INFORMED DECISIONS: A PRACTICAL APPROACH TO SELECTING WATER MICROBIOLOGY TESTS

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ABSTRACT (500 WORDS MAXIMUM)

The evaluation of waterborne pathogen risks often leads to requests for microbiological testing. However, the limitations of microbiology tests are not always properly considered. This can lead to the selection of inappropriate tests, which may misallocate resources and create inaccurate perceptions of the risk.

This paper presents a set of questions that serve as a practical tool for assessing the appropriateness and effectiveness of microbiology tests. While these questions are not necessarily new, they are not always applied. By ensuring that these questions are addressed, water quality professionals can make better-informed decisions when selecting tests, ultimately improving water resource management and public health protection. The questions are structured around the following concepts:

1. **What are quantitative Health Outcome Targets, and how do they influence the selection of microbiology tests?** This question considers Health Outcome Targets based on diarrhoeal disease frequencies (e.g., 1 infection per 10,000 individuals per year) and emphasizes the importance of establishing such targets before selecting microbiology tests.

2. **How to evaluate logical relationships between microbiology tests and Health Outcome Targets.** The discussion emphasizes the need to ensure that every link in the relationship is valid. If not, tests might be conducted that don't meaningfully reduce risk. Inconsistencies should not be overlooked.

3. **How to evaluate the performance characteristics of microbiology tests.** Even if a test is logically related to a Health Outcome Target its performance characteristics may not be adequate? The discussion provides a summary of the properties of microbiology tests that should be considered. These include the feasibility of collecting representative samples, the efficiency with which target microorganisms are detected, the alignment of turnaround times with public health requirements and the implications of method uncertainty.

The paper provides a discussion of each concept, offering examples and practical guidance for water quality professionals seeking to implement microbiology tests. A concise overview of the concepts and questions is also presented in the quick-

reference guide in Appendix 1. Readers are encouraged to assess the value of the tests they conduct against this reference.

KEYWORDS

waterborne pathogen risks, microbiology tests, public health, water quality management

PRESENTER PROFILE

Neil Leat is currently the Head of Microbiology at Watercare Laboratory Services. He holds a PhD in Microbiology from the University of Cape Town. Previously, he served as a Senior Scientist at Rand Water and a Senior Researcher at the Council for Scientific and Industrial Research in South Africa. Neil has served on both the South African Bureau of Standards Technical Committee on Water Quality and the Specialist Technical Committee on Water Testing for the South African National Accreditation System.

1. INTRODUCTION

In the context of microbiological water safety, Health Outcome Targets define acceptable levels of risk. They do this by setting quantitative benchmarks based on the health impacts of waterborne pathogens.

Health Outcome Targets are useful for guiding management decisions, including the selection and application of microbiology tests. This is true whether the targets are prescribed nationally, as recommended by the World Health Organisation (WHO) (2017), or from a critical evaluation of the targets of other countries.

The limitations of microbiology tests are not always obvious. Without understanding the limitations there is a danger of wasting resources on tests that do little to help manage risks. Based on my 15 years of experience as a microbiologist in the water industry, I've observed that requests for microbiology testing often neglect the following questions.

- **What Health Outcome Target is the requested test intended to support?** This paper emphasizes the importance of being aware of Health Outcome Targets and considering them before selecting microbiology tests.

- **Is there a clear logical relationship between any proposed testing and the corresponding Health Outcome Target?** The discussion will consider examples of inconsistencies between tests and Health Outcome Targets.

- **Are the performance characteristics of the tests adequate? Can they genuinely contribute to achieving the Health Outcome Target?** The discussion provides a summary of the properties of microbiology tests that should be considered relative to the Health Outcome Target they support.

When inconsistencies are identified between tests and targets, it is important that they are not overlooked. However, the discovery of inconsistencies may conflict with a perceived need to continue testing. This can lead to justifications for testing that are not entirely sound. These range from "*Appeals to authority*" to "*Arguments from adverse consequences*". This paper will consider these reasoning patterns and explore why they do not provide a sound justification for continued testing.

Where possible, the examples provided throughout the paper are drawn from specific scenarios I have encountered, many of which focus on drinking water. However, the concepts can be extended to other water types. My hope is that by sharing these experiences I will help water professionals select microbiology tests more effectively. To this end, I encourage readers to evaluate the tests they request against the concepts and questions in this paper and in the summary provided in the quick-reference guide in the Appendix.

2. WHAT ARE HEALTH OUTCOME TARGETS?

In a technical sense "safe" often means that risks have been minimised to a tolerable level, not that they have been eliminated. In the context of water safety,

Health Outcome Targets provide a specific measure of the level of risk tolerated from waterborne pathogens.

Health Outcome Targets are typically expressed in terms of metrics like maximum tolerated annual infection rates or Disability Adjusted Life Years (DALYs) (Figure 1). Maximum tolerated infection rates are intuitively easy to understand. The DALYs metric is more complex and considers both infection rates, the probability of illness developing after infection, and the severity of the illness.

A discussion on the merits of infection rate targets versus DALY targets will not be considered here but can be found in Schoen et al. (2023). All that is required here is an understanding that Health Outcome Targets specify the maximum residual risk that can be tolerated due to waterborne pathogens. As such they provide a beacon which can guide management decisions.

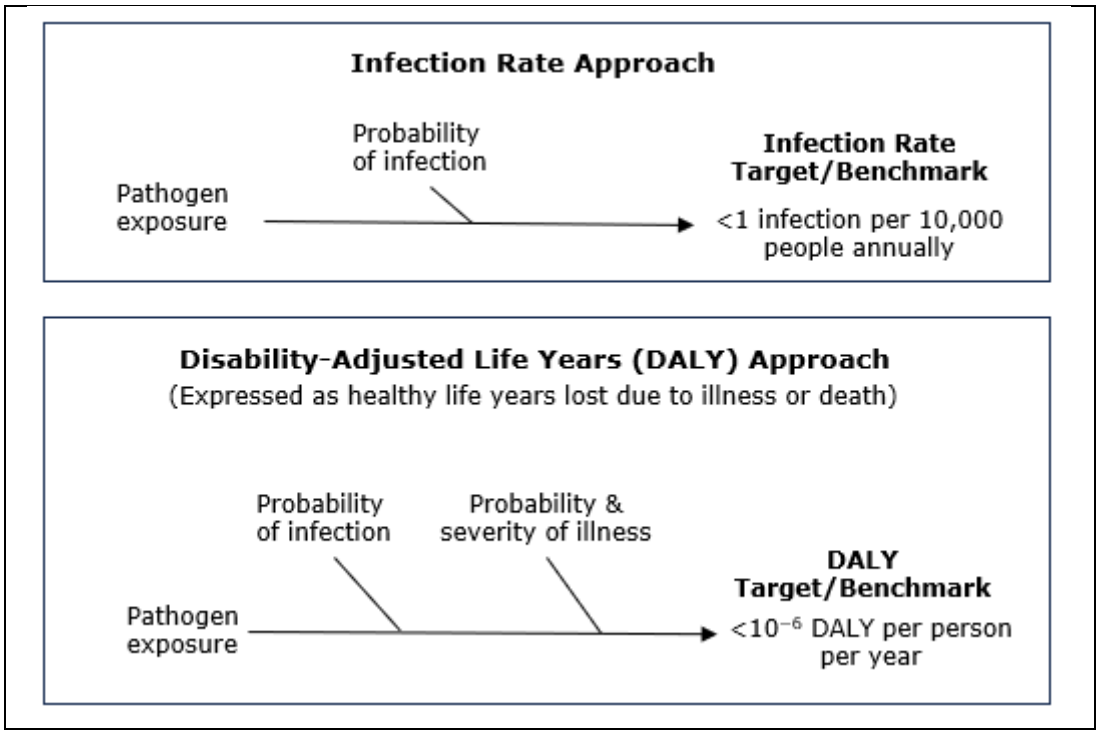

Figure 1: Health Outcome Targets expressed as maximum tolerated infection rates *or Disability Adjusted Life Years (DALYs). The former is a direct count of infections the latter considers both the number of infections and the severity of each infection. The details of how to calculate DALYs are beyond the scope of this paper but can be found in the WHO Drinking Water Guidelines (WHO, 2017). Figure adapted from WHO (2017) and Schoen et al. (2023).*

The WHO recommends setting Health Outcome Targets as high-level policy targets at a national level (WHO, 2017). This recognises that deciding on acceptable levels of risk is a sensitive matter which requires consideration of local environmental, cultural, economic, and political considerations (WHO, 2017). However, when set, they provide clear quantitative objectives that water management activities can aim to achieve. They clarify what level of risk is considered "safe"; they allow for more coordinated action towards a defined target; and by providing a benchmark, they enable verification that risks are reduced to an acceptable level.

It is worth noting that the concept of using Health Outcome Targets has been adopted widely over the last two decades. The third edition of the WHO Drinking Water Guidelines recommended their use as early as 2004 (WHO, 2004). Examples of subsequent acceptance include the Australian Guidelines for Water Recycling (NRMMC, EPHC & AHMC, 2006; NRMMC, EPHC & NHMRC, 2008), the Australian Drinking Water Guidelines (NHMRC, 2022), and Health Canada (2019).

Even in situations where there isn't a nationally set Health Outcome Target, there remains significant value in considering targets set in similar contexts. Recognising Health Outcome Targets that could be relevant, along with an appreciation of the corresponding maximum tolerated pathogen concentrations, can enhance decisions aimed at improving water safety, including the selection of microbiology tests.

3. HOW DO HEALTH OUTCOME TARGETS INFLUENCE THE SELECTION OF MICROBIOLOGY TESTS?

For a Health Outcome Target to be useful, it needs to be translated into a maximum tolerable pathogen concentration. This value provides a metric that water service providers can actively work to attain.

The translation is achieved using a Quantitative Microbial Risk Assessment (QMRA). A QMRA is a systematic approach used to estimate the risk of illness from exposure to specific waterborne pathogens. It quantifies the potential health risks by considering factors like the concentration of pathogens in water, exposure pathways, and the likelihood of infection upon exposure. In essence, QMRAs translate a Health Outcome Target into its equivalent pathogen concentration.

To illustrate the application of a QMRA, consider the Health Outcome Target referenced by the WHO of 10^{-6} DALYs per person per year (WHO, 2017). The WHO used a QMRA approach to determine that the maximum concentration of *Cryptosporidium* in drinking water to meet this target is approximately 0.063 oocysts per 100L, assuming a consumption of 1.0 litre of cold tap water per person per day (WHO, 2009, Section 6.7).

It is important to note that there is typically an uncertainty associated with any QMRA calculation and that different QMRA approaches, and assumptions will influence the results. QMRA methodologies are complex and nuanced but provide an effective mechanism for translating Health Outcome Targets into maximum tolerated pathogen concentrations. For a comprehensive review of QMRA methodologies see Owens et al. (2020).

Once the maximum tolerable pathogen concentration has been estimated, it informs the setting of other water quality and treatment parameters including: i) Maximum Acceptable Values (MAVs) and ii) Performance Targets. These in turn influence the selection of microbiology tests as illustrated below:

- Microbiology Tests and Maximum Acceptable Values (MAVs): Microbiology tests can be used to verify compliance with MAVs. However, MAVs for

drinking water are often of limited use because extremely low concentrations of pathogens present significant risks. These concentrations are often far below the detection limits of microbiology methods. The WHO specifically states that for drinking water "*Concentrations of pathogens equivalent to a Health Outcome Target of 10^{-6} DALY per person per year typically amount to less than 1 organism per 10^4–10^5 litres*" (WHO, 2017).

- Microbiology Tests and Performance Targets: Microbiology tests can help assess pathogen concentrations in source waters and therefore the log reduction required to ensure the concentration falls below the maximum tolerable level. They can also be used to verify the efficiency of individual treatment processes.

In summary, Health Outcome Targets are underpinned by secondary targets like MAVs and Performance Targets. When appropriately selected, microbiology tests can support the implementation of these targets.

4. VERIFYING THE RELATIONSHIP BETWEEN MICROBIOLOGY TESTS AND HEALTH OUTCOME TARGETS

4.1 BEGIN BY SELECTING THE "RIGHT" MICROORGANISM

As a point of departure, ensure that the microorganism selected for testing is relevant. While the differences between process indicators, faecal indicators, and reference pathogens might seem extremely obvious, there still seems to be some confusion when tests are requested. This is exacerbated by the fact that some indicators have similar names (e.g., "total coliforms" vs "faecal coliforms" or "faecal coliforms" vs "faecal streptococci"). Given that confusion persists, a brief overview of indicators and reference pathogens is provided below. This is followed by examples to illustrate how indicators are sometimes confused in practice.

- **Process indicators:** An example would be total coliforms, which are naturally present in the environment and provide an indication of the general bacterial content of water samples. They are used to measure the efficiency and effectiveness of treatment processes. They should be present before treatment and be reduced or absent after treatment.

- **Faecal indicators:** Indicate the potential presence of faecal contamination and, by extension, faecal pathogens. Examples are faecal coliforms or *Escherichia coli (E. coli)*.

- **Reference pathogens:** Reference pathogens serve as standard microorganisms to model the behaviour and risks of a broader group of pathogens in QMRA studies. The selection of reference pathogens is based on their significance to public health, their ability to represent a wider group of pathogens, and the available data on their characteristics. Illustrative examples of reference pathogens, as cited from Ashbolt (2015), include:

- Rotaviruses: As a reference for enteric viruses due to their widespread occurrence and the significant gastroenteritis associated with infection.

- *Campylobacter jejuni*: A reference for waterborne enteric bacterial pathogens.

- *Cryptosporidium parvum*: A reference for protozoan parasites. Its selection is attributed to its widespread presence in water sources, and the considerable health risks it presents.

The selection of reference pathogens is a nuanced process beyond the scope of this paper. Owens et al. (2020) and Ashbolt (2015) can be consulted for more information on this. However, improving the selection of indicators is more straightforward, particularly if the differences between them are understood and the errors illustrated by the examples below are avoided.

- **Requesting total coliform results for environmental samples when there is no treatment process being evaluated**. Total coliforms are naturally present in the environment and are not reliable indicators of faecal pollution. Unless a treatment process is being evaluated it is difficult to understand what value the total coliform results might have for environmental samples. When this happens, it is possible the intent was to test for faecal coliforms, but total coliforms were requested in error.

- **Interpreting total coliform results as faecal coliform results for drinking water samples.** When this happens a problem that should be addressed as a treatment issue is interpreted instead as evidence of faecal contamination.

- **Requesting faecal coliform and *E. coli* tests on the same sample:** Faecal coliforms and *E. coli* are both faecal indicators from the coliform group. They serve an equivalent purpose so selecting both tests on the same sample represents a duplication of effort. On a separate but related note, the insistence on faecal coliform results instead of *E. coli* results forces laboratories to maintain two separate tests for the same purpose.

4.2 REVIEW THE LINKS BETWEEN THE TEST AND THE TARGET

This section presents two hypothetical examples of logical inconsistencies between microbiology tests and Health Outcome Targets. These examples demonstrate that tests, which at first seem to align with targets, may not actually do so upon detailed examination.

Misaligned Health Outcome and Water Quality Targets.

- A Health Outcome Target of 10^{-6} DALYs per person per year is set for *Cryptosporidium* oocysts in drinking water. The corresponding maximum acceptable oocyst concentration in drinking water determined by QMRA is ≤ 0.063 per 100L.

- Despite this, a Water Quality Target (MAV) for drinking water is set at <1 *Cryptosporidium* oocyst per 100L. The selection of the MAV may have been influenced by the limitations of the associated microbiology test.
- Clearly the maximum oocyst concentration and Water Quality Targets are not aligned "≤ 0.063 per 100L" vs "<1 per 100L".
- This means the requirements of the Health Outcome Target are more stringent than the MAV. The target would be breached long before the MAV is exceeded.
- A logical inconsistency exists because microbiology tests aimed at showing compliance with the MAV would not necessarily show compliance with the Health Outcome Target.

A Performance Target that is not adequately supported by microbiology testing.

- A Performance Target is required for *Cryptosporidium* oocyst removal from source waters.
- To set the Performance Target (Log reduction), the concentration of oocysts in the source waters must be estimated.
- Unfortunately, the microbiology tests used to assess the concentration of oocysts have poor recovery rates, high levels of uncertainty and their cost means they cannot be used frequently enough to obtain representative results.
- If the microbiology results cannot provide a reliable indication of the oocyst concentration in source waters, they are not a reliable source of information to determine the log reduction requirement.

These two scenarios illustrate at a simple level how the relationship between microbiology tests and Health Outcome Targets may not be aligned. Where a test does not have a quantitative relationship with the Health Outcome Target, this should not simply be overlooked. If testing proceeds it should be in full recognition of the inconsistencies.

5. ASSESSING THE PERFORMANCE CHARACTERISTICS OF MICROBIOLOGY TESTS.

Even if an appropriate microorganism is selected, and there is conceptual alignment between the test and the Health Outcome Target, it does not mean that performance characteristics of the test are adequate. For tests to contribute, their performance must be such that they can meaningfully inform efforts to reduce risks. Parameters to consider include: the feasibility of collecting representative samples, target organism recovery rates, the suitability of turnaround times and the implications of uncertainties associated with test results. Each of these factors will be considered individually below:

5.1 Representative sampling

For results to be of value, representative sample collection is essential. A key factor to consider is how heterogeneous the water being sampled is over space

and time. The higher the level of heterogeneity the higher the number of samples needed to obtain representative results. Sources of variation could be related to hourly changes in water demand, seasonal changes, as well as long-term patterns like droughts. Sporadic high rainfall events introduce an additional layer of complexity, especially given that they are often associated with an increased risk from waterborne pathogens. The ability to collect enough data is further constrained where the cost of testing is high which places restrictions on the frequency with which tests can be conducted (e.g., Enteric virus and *Cryptosporidium* and *Giardia* testing).

To ensure the accuracy and reliability of results, it is important to have a statistically valid sampling plan. Such a plan should be designed to provide genuinely representative data across varied conditions. However, when faced with constraints, it's vital to acknowledge any potential shortcomings in representation. Extreme caution should be exercised when interpreting statistics derived from limited data or an insufficient number of samples.

5.2 Recovery Rates:

A crucial property of a test method is its capacity to recover and detect target microorganisms. It is important to appreciate whether the test can detect the target microorganisms at levels significant to public health.

Consider the challenges of direct tests for enteric viruses in water matrices. Methods for analysing water for viruses often exhibit variable and suboptimal recovery rates. As an example, consider the study conducted by Petterson et al. (2015) where samples from the inlet of a drinking water treatment plant on the Glomma River in Norway showed low mean recovery rates: Human adenovirus at 1.2%, Noroviruses GI at 0.15%, and Noroviruses GII at 0.053%.

It is important to recognise when microbiology methods have such low recovery rates and assess whether it is even possible to obtain reliable data on the organisms being tested. For instance, the value of costly enteric virus testing is questionable in cases where recovery rates can be as low as 1%, and variations between tests are hard to correct.

5.3 Turnaround Times:

Public health decisions are often time sensitive. If results are not timely, an otherwise robust result may be of limited value. Consider the example below:

Detection of enteric viruses using cell culture methods involves inoculating concentrated and purified viruses from water samples onto susceptible cell lines to detect cytopathogenic effects. The turnaround time for this method varies based on the virus and the cell line used, typically ranging from 5 to 14 days, but it can sometimes extend to several weeks.

In evaluating such methods, it is crucial to assess the turnaround time against the intended use of the data for public health decision-making. If there is a discrepancy between the time required to take meaningful action and the test's turnaround time, it must be addressed. Only then can the test contribute meaningfully to public health outcomes.

5.4 Method Uncertainty:

Uncertainty is defined as the range within which the true value resides, expressed with a specified level of confidence. Every microbiology test result carries an inherent level of uncertainty. Ignoring this uncertainty can lead to an incomplete understanding of the result. A result with minimal uncertainty can be used with higher confidence in decision-making, while a result with significant uncertainty might require more caution.

To illustrate this, consider the scenario where microbiology tests are used to verify the effectiveness of a treatment process. This is achieved by comparing reference pathogen concentrations before and after treatment. When only a few tests are conducted using a method with a high level of uncertainty, it becomes challenging to discern whether differences before and after treatment are due to treatment effectiveness or test variability. Increasing the number of tests can help mitigate the impact of method uncertainty. However, the decision to increase the test frequency can only be made if there is an initial awareness and understanding of the method's inherent uncertainty.

Focusing solely on the test result without considering its uncertainty risks overlooking a critical dimension. Understanding uncertainty ensures that statistically valid inferences can be made from the results in question.

5.5 Evaluating Alternatives:

In water microbiology testing, the choice of method can significantly influence both the speed and cost of obtaining results. As an example, consider Heterotrophic Plate Count (HPC) testing, which has been in use for over a century, and which can take several days to produce results. In contrast, flow cytometry, using standardised methods that involve staining with SYBR Green and propidium iodide, can deliver almost immediate results, and which also offer far greater detail about the diversity and abundance of microorganisms in water samples (Schönher et al., 2021). By understanding and considering these alternative testing methods, laboratories can make informed decisions that ensure accurate and timely results while optimising resource allocation. Embracing new technologies can enhance testing efficiency and broaden opportunities for risk reduction.

6. AVOIDING REASONING ERRORS AFTER DETECTING INCONSISTENCIES

When inconsistencies are identified, it is important that they are not overlooked. However, the discovery of inconsistencies may conflict with a perceived need to continue testing. Individuals may find it difficult to reconcile a strong need to test with a newly identified inconsistency. This can lead to justifications for continued testing that are not entirely sound. The justifications often fail to focus on the actual properties of the test and the context in which it is used. Instead, they tend to refer to information that indirectly supports continued testing. Examples of these types of reasoning patterns are itemised below:

Appeals to authority: Relying on an authoritative opinion as the primary motivation for continuing testing without directly addressing the inconsistency in question.

- *"The proposed testing is best practice."* Referring to "*Best practice*" without clarifying the foundation of that practice does not address the gap. "*Best practice*" holds value only if it is firmly rooted in logic. If there is a logical basis for the "*Best practice*", then it is important to explore that logic directly. Otherwise, invoking "*Best practice*" runs the risk of becoming a rhetorical device.

- *"A prominent microbiology professor recommended the testing"* While expert opinion can be invaluable as a guide, the source of the opinion, is not on its own, a reason to overlook an inconsistency. Experts can be influenced by biases, conflicts of interest, or outdated information. Experts may also be tempted to offer opinions outside their field of expertise.

- *"If we follow the Australian guidance document everyone will accept that we have tested the right parameters":* The context in which the guidance was document was issued may be different from the context in which is subsequently used. Consulting guidance documents from other contexts is valuable, however, there is always a possibility that the information in the guidance document is not relevant.

Appeals to common or established practice: Arguing based on historical precedent or perceived widespread acceptance.

- "*We've always done it this way*", "*Everyone is familiar with this testing process, why should we change it"* and "*There is an expectation for us to continue with it*." The fact that a practise is common does not in itself make it effective. It is entirely possible that common practices can be outdated, inefficient and flawed.

Arguments from adverse consequences: Making decisions based on fear of negative outcomes unrelated to pathogen risk reduction.

- *"If we didn't test and something went wrong, we would be blamed for not conducting the testing, even though we realise it does little to reduce the risk*". The justification for conducting the tests is based on the negative consequences (reputational risk) that would arise, rather than on the actual efficacy or relevance of the tests. While the reputational risk is a very legitimate concern, transparency about the limitations of tests is also important. Presenting test results as an indication of safety when they may be of limited value, can also pose challenges.

Anchoring: Giving too much weight to an initial piece of information, and then overlooking other crucial data, leading to incomplete decisions.

- "*Adenoviruses are always present when other enteric viruses are present. It follows that we should use them as indicators, even though the methods to detect them have substantial limitations*." The justification is based on the strong association of Adenoviruses with the presence of other enteric viruses. However, the implications of the limited detection methods are necessarily explored.

Many of the reasoning approaches mentioned above are useful during the initial shortlisting of microbiology tests. However, they are not in themselves technical assessments that address logical inconsistencies in a specific use case. They can serve as prompts for further investigation but not as bridges for logical gaps between the tests and Health Outcome Targets.

Recognition of these reasoning patterns represents the first step in addressing them. If they are observed, it is worth deliberately identifying them and examining them in more detail to understand the core reasons behind decisions. It is also important to notice shifting justifications should they occur. Deliberately tracking these shifts can be crucial to ensure one problem is not overlooked as attention shifts to another. Periodic reviews of decisions can help maintain alignment with relevant Health Outcome Targets and promote a more informed decision-making process.

7. CONCLUSIONS

In the context of microbiological water safety, aligning microbiology tests with Health Outcome Targets is valuable. This paper has highlighted the importance of:

Understanding Health Outcome Targets: Whether set nationally or derived from international standards, these targets provide clear benchmarks for water quality management. When translated into maximum tolerated pathogen concentrations, they guide the selection of appropriate microbiology tests.

Evaluating Microbiology Tests: It's vital to ensure that the chosen tests are both technically sound and relevant to the Health Outcome Targets. This involves assessing the test's performance characteristics, such as the feasibility of collecting representative data, its recovery rates, and turnaround times.

Addressing Inconsistencies: When discrepancies between tests and Health Outcome Targets are identified, they should be addressed directly. Relying on unsound reasoning patterns, such as appeals to authority or common practice, doesn't resolve core technical issues.

By sharing these observations, I hope to offer some perspective to those requesting microbiology tests. To support this goal, I recommend that readers review the tests they request against the concepts and questions in this paper and in the summary provided in the quick-reference guide in the Appendix.

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APPENDIX 1: QUICK REFERENCE FOR MICROBIOLOGY TEST SELECTION

Foundation concept

What does safe actually mean?

- Safe cannot mean "*totally risk-free*". The elimination of all risks is not feasible.
- Safe means risks are reduced to "acceptable levels " defined by Health Outcome Targets.

What are Health Outcome Targets?

- **Definition:** Health Outcome Targets are a quantitative measure of the level of risk accepted from waterborne pathogens. They are typically set in a specific context (e.g. *Cryptosporidium* in drinking water).
- **Expressed as:** Maximum tolerable Infection rates or Disability Adjusted Life Years (DALYs)
- **Why should you care:** The targets provide a clear benchmark defining what constitutes safe water.
- **Set by:** WHO recommends that Health Outcome Targets be set as high-level targets at national level (WHO, 2017)
- **Global Use:** Adopted at a national level by countries like Canada, 2019 & Australia, 2022. Less well established in New Zealand.
- **How are they applied:** They inform the selection of secondary targets like Maximum Acceptable Values and Log Removal Targets. These secondary targets must be set in such a way that the Health Outcome Targets will be met.
- **How do they relate to microbiology tests:** Microbiology tests should provide information that is essential to reduce the risks so that Health Outcome Targets are met. If they don't it becomes more difficult to define how the tests contribute to public health.

Questions to ask before selecting microbiology tests

- **Have you identified a Health Outcome Target?** Without the target, the destination isn't clearly defined.
- **Is the microorganism you want to test for relevant?** Get the basics right: Know the difference between process indicators, faecal indicators, and reference pathogens. Misunderstandings happen and lead to wasted resources.
- **Clearly define the relationship between the microbiology tests and the Health Outcome Target?** Even one broken link invalidates the logical chain.
- **Will the testing give you representative results?** Can you sample frequently enough over a wide enough area to obtain representative results? If you can't obtain representative results how is this acknowledged? Be extremely cautious of statistics derived from small amounts of data.
- **What is the test's recovery rate?** If very low levels of the target organism are recovered how is this accounted for when the results are used?
- **What is the turnaround time?** Are results timely enough for public health decisions?
- **What is the method uncertainty?** High levels of uncertainty may require more samples to get reliable results.
- **Are there alternative approaches?** Are there alternative tests methods? Are there other ways of mitigating the risk so that microbiology testing isn't even needed?

Logical Error Trapping? When logical inconsistencies are identified they may meet with a strong perceived need to continue testing. Invalid arguments may emerge.

- **Appeals to Authority:** Relying on an authoritative opinion as the primary motivation for testing without directly addressing the inconsistency.
- **Appeals to Common Practice:** The fact that a practice is common does not in itself make it effective. It is entirely possible that common practices can be inefficient and flawed.
- **Anchoring:** Giving too much weight to an initial piece of information, and then overlooking subsequent weaknesses.
- **Argument from Adverse Consequences:** "*If we didn't test and something went wrong, we would be blamed for not conducting the testing, even though we realise it doesn't reduce risks*". The justification is based on the reputational risk and not on the efficacy of the tests.

Conclusion: By addressing these key areas, water professionals can make better-informed decisions about microbiology testing. This will optimise the use of resources and enhance public health protection.