LOG-REDUCTION: WHEN AN AVERAGE ISN'T AVERAGE AT ALL

A research overview with implications for drinking water safety

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KEY MESSAGES

- Averaging log-reduction values overstates treatment performance
- Reliance on average log-reduction can lead to inadequate treatment
- In QMRA, average log-reduction values can lead to underestimation of risk, often by an order of magnitude (10x) or more

WHY WAS THIS DONE?

Ensuring that water is microbiologically fit for purpose requires description of the removal or inactivation of pathogens by treatment. This treatment performance is commonly expressed in terms of log-reduction (e.g., 90% reduction = 1-log, 99% reduction = 2-log). Treatment performance can vary in time or between treatment trains/systems. An expression of the treatment performance that can be expected on average is critical for design and operational decision-making. Quantitative microbial risk assessment (QMRA) is often used in these processes. Critically, the implications of averaging log-reduction values have not previously been rigorously discussed.

> "The net pathogen removal is of particular importance in assessing risk and protecting public health. Nevertheless, the average log removal is often quoted..."
>
> **– Gale & Stanfield, 2000**

APPROACH

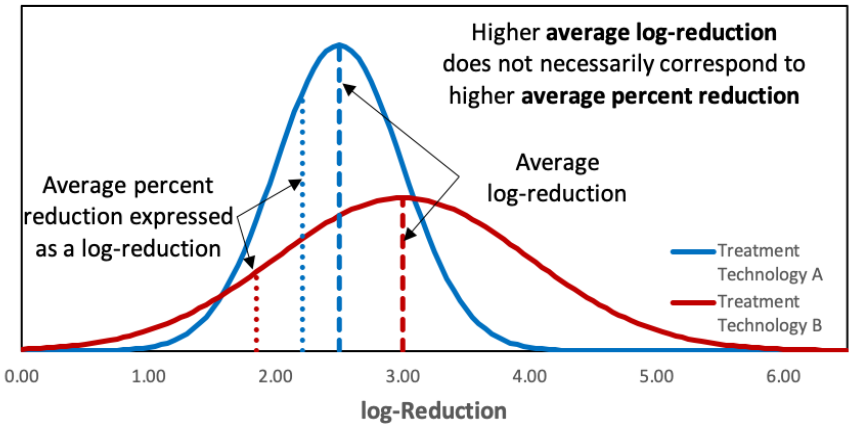
Most people recall that the average of several log values (e.g., log-removal of *Cryptosporidium* oocysts by filtration) is not mathematically equivalent to the logarithm of the averaged original (i.e., non-logarithmic) values. Nonetheless, the use of the average of several log-reduction values is widespread in practice, policy, and research. A mass balance approach was used to describe passage of enteric pathogens through treatment systems and prove that average log-reduction characteristically overstates average treatment performance. We explored whether or not hypothesis testing concerning averaged log-reduction values can yield reliable inferences for decision-making. The inadequacy and potential public health implications of relying on averaged log-reduction values in QMRA were demonstrated using an example from the World Health Organization (WHO) QMRA guidance document for water safety management.

FINDINGS

1) An "effective log-reduction" value describes average treatment performance without the error inherent to averaged log-reduction values

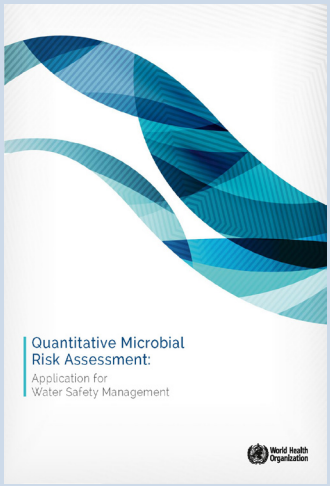
2) Using averaged log-reduction values in QMRA can lead to underestimation of risk and overconfidence in the adequacy of treatment processes

3) Commonly utilized microorganism elimination credits overstate average treatment performance, sometimes by an order of magnitude (1-log) or more



"Overlooked statistical error of averaging logarithmic values in the calculation...caused risk to be underestimated by approximately 0.9-log and resulted in an erroneous conclusion that adequate treatment was provided."

– Schmidt et al., 2020



Links to WHO (2016) are further discussed in doi: https://doi.org/10.1016/j.watres.2020.116266

IMPLICATIONS

For drinking water utilities: Percent reduction values should be averaged and then expressed as a log-reduction —this is the "effective log-reduction".

For treatment technology developers: Technology performance demonstrations should compare average percent reduction values. Statistical analysis of mean log-reduction can sometimes make treatment performance appear *significantly* better when it is actually worse.

For risk assessors: Averaged log-reduction values are commonly reported in the literature and sometimes recommended for use as default treatment credits. Using these values understates risk, sometimes by an order of magnitude or more.

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