Optimizing chlorination for water safety and acceptability in emergency water supplies in humanitarian crises using a deep composite neural network

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Water Safety in Humanitarian Response

- More people are displaced in refugee or peri-urban settlements than ever and waterborne diseases are a major threat
- Free residual chlorine (FRC) is used to **disinfect** and **protect** against recontamination, but post-distribution decay leaves water vulnerable
- FRC targets must balance need to **protect public health** while **ensuring taste & odour (T&O) acceptability** in a context with highly uncertain decay behaviour
- The **Safe Water Optimization Tool (SWOT)** is a web-based water quality modelling tool that provides site-specific, evidence-based FRC targets to maximize public health protection.

Research Question

How can we progress the SWOT to balance public health protection and consumer acceptability?

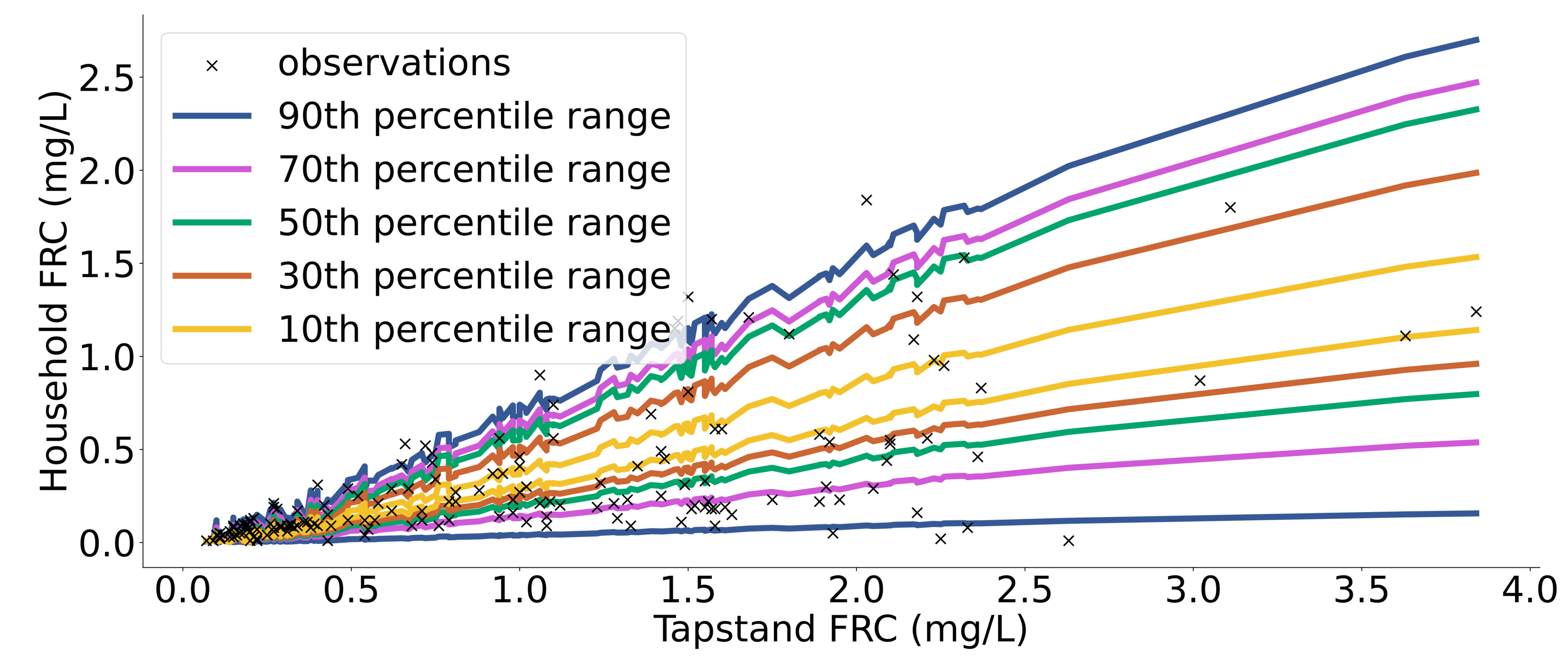
Specific Objectives

1. Improve SWOT probabilistic FRC modelling using Deep Composite Quantile Regression Neural Networks (DCQRNNs)
2. Model the probability of acceptance/rejection of drinking water T&O based on water-user's perceptions
3. Optimize FRC target for water safety and acceptability

Methods

Site	Kyaka II refugee settlement, Uganda, Piped water supply network
Water Quality Data	Paired tapstand FRC, conductivity, and water temperature and household FRC (N=216 training, 223 testing)
Taste and Odour Data	140 surveys using nine-point flavour rating assessment
Water Quality Model	DCQRNN predicting 22 quantiles 5 hidden layers with hyperbolic tangent activation Input variables: tapstand FRC, conductivity, water temperature, storage duration
Taste and Odour Model	Ordinary Least Square Regression of Percent Accepting/Rejecting

Water Safety Modelling Results



Percent Capture	Percent Capture of Critical Values	Average Quantile Score	CRPS
98%	99%	0.064	0.14

Fig 2. DCQRNN predictions of the 10th, 30th, 50th, 70th, and 90th percentile range and independent holdout test set performance. Predictions across the quantiles track well with the data and performance is very good.

T&O Modelling Results

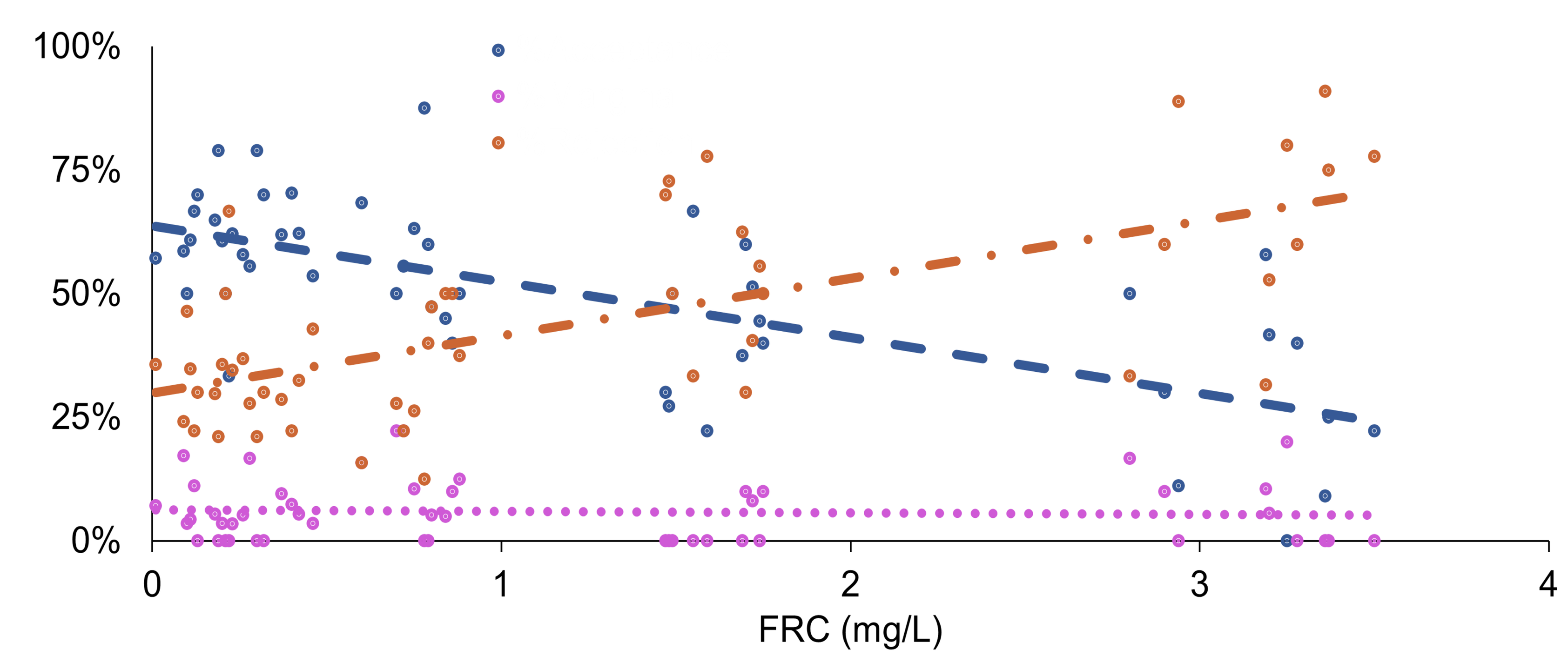


Fig 3. Taste and Odour acceptability as a function of FRC. Rejection increases and acceptance decreases as FRC rises, but small relative to intercepts. Very high rejection at intercept (FRC = 0 mg/L) means possible non-chlorine T&O challenges affecting results.

Combining Risk Models

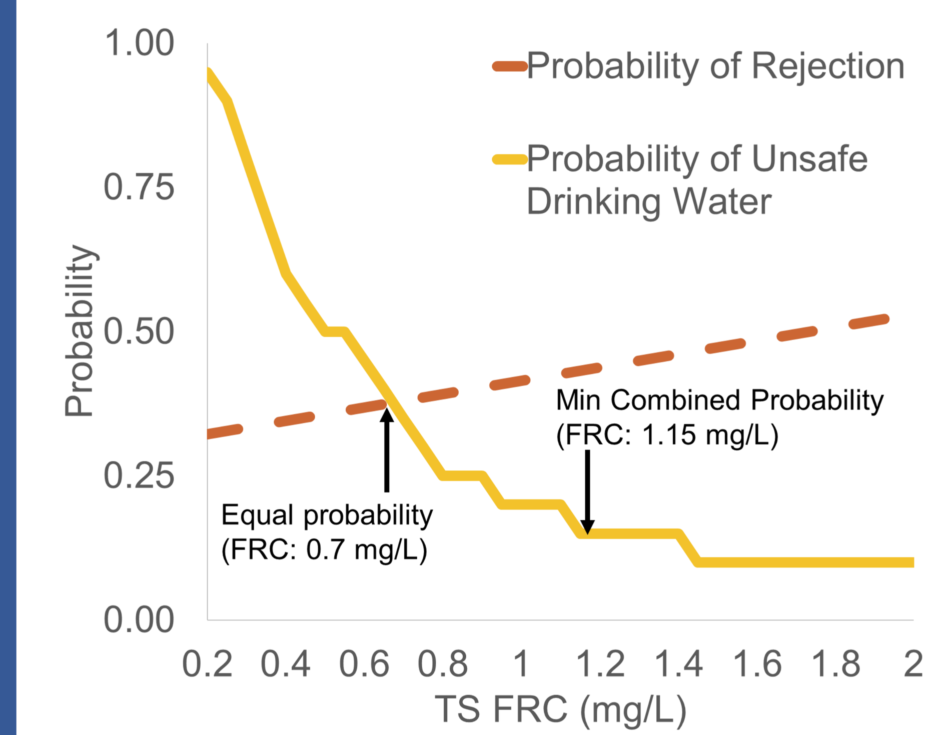


Fig 4. FRC target optimization for water safety and acceptability. At 0.7 mg/L there is equal probability of rejection and unsafe drinking water (both 0.35). Lowest combined probability at tapstand FRC of 1.15 mg/L, but here rejection is quite high (0.43). Optimal point depends on context (alternative water sources, past outbreaks).

Conclusions

- DCQRNNs perform well modelling post-distribution FRC
- Combining water safety and T&O models in the Safe Water Optimization Tool (SWOT) yields chlorination targets that balance public health and acceptability.
- SWOT approach supports water system operations in humanitarian response
- Future need: understand rejection at FRC = 0 mg/L
- Future applicability in urban/peri-urban settings with decentralized water systems

Safe Water Optimization Tool

Learn more at safeh2o.app or reach out at hello@safeh2o.app!
We'd love to hear from you!

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