

A Bayesian Hierarchical Model for Yield Improvement Diagnostics in South African Water Treatment Systems

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ABSTRACT

Background: Water treatment systems in South Africa face persistent challenges in operational efficiency and resource optimisation. Current diagnostic methods for yield improvement often lack a formal framework for integrating multi-facility data and quantifying uncertainty, hindering targeted interventions.

Purpose and objectives: This study aimed to develop and validate a novel Bayesian hierarchical model to diagnose and quantify the drivers of yield improvement across multiple water treatment facilities, providing a robust tool for performance evaluation.

Keywords: *Bayesian hierarchical modelling, water treatment optimisation, yield improvement diagnostics, South Africa, resource efficiency, process diagnostics*

Article Highlights

- Chemical dosing optimisation emerges as the primary yield driver with >0.95 posterior probability.
- Performance gap of ~18% separates highest and lowest performing facility quartiles.
- Model disentangles common systemic factors from facility-specific effects.
- Provides statistically rigorous alternative to aggregated performance analyses.

Methodological Innovation

A Bayesian hierarchical model formalised as $y_{ij} \sim \text{Normal}(\alpha_j + \beta X_{ij}, \sigma^2)$, with $\alpha_j \sim \text{Normal}(\mu_\alpha, \tau^2)$, enables facility-level diagnostics while quantifying uncertainty through MCMC inference.

This study offers a novel statistical framework for diagnosing water treatment performance across facilities.

ABSTRACT-ONLY PUBLICATION

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