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Statistical model for identification of the relationship between SARS-CoV-2 prevalence and wastewater concentration with vaccination and delta variant mutation

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Robust statistical models relating wastewater to community disease prevalence still need to be developed. Therefore, this study conducted the Bayesian inference to identify the relationship between community wastewater for SARS-CoV-2 concentrations and the prevalence of SARS-CoV-2 antibodies. In addition, the dynamical survival analysis (DSA), a framework for using survival analysis methods to build approximate models of individual-level information, was applied to the compartmental model using ordinary differential equations.

Using an expanded Susceptible-Infected-Recovered (SIR) model with vaccinated and delta variant infection compartments, the longitudinal estimates of the disease prevalence were obtained and compared with the wastewater concentrations using a generalized linear model. The Bayesian Markov Chain Monte Carlo (MCMC) method was utilized to estimate model parameters. The model analysis revealed significant temporal differences in epidemic peaks. The results showed that in some areas, the average incidence rate based on serological sampling was 50% higher than the health department rate based on convenience sampling. In the generalized linear model, a one copy per ml-unit increase in weekly average wastewater concentration of SARS-CoV-2 corresponded to an average increase of 1–1.3 cases of SARS-CoV-2 infection per 100,000 residents.

The analysis indicates that wastewater may provide robust estimates of community spread of infection, in line with the modeled prevalence estimates obtained from stratified randomized sampling, and is therefore superior to publicly available health data. In addition, the analysis also identified that vaccination

might reduce the prevalence and delta variant mutation affected significantly, increasing the infection.

Keywords: COVID-19, Wastewater-based epidemiology, Bayesian inference, Seroprevalence, Dynamical survival analysis (DSA)