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Water quality modelling to assess sources and transport of pathogens within uMsunduzi catchment, South Africa

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Water quality modelling is essential to integrated water resources management and decision-making, as it improves the understanding of the spatial and temporal dynamics of chemical and microbial pollution in a river system. Understanding of the spatio-temporal dynamics of pollution and accurate prediction of its pollution hotspots are vital to improving the microbial quality of surface water. South African rivers generally receive waste from inadequate wastewater infrastructure, mines, and farming activities, among others. The uMsunduzi River in KwaZulu-Natal, South Africa, is among rivers with recorded poor to very poor water quality. To identify parts of the uMsunduzi River that are polluted by *Escherichia coli (E. coli)* and *Cryptosporidium*, chosen to represent bacteria and protozoan parasites respectively, this study mapped out pollutants emanating from point and non-point sources using the Soil and Water Assessment Tool (SWAT) model. SWAT uses a combination of empirical and physically based equations that use readily available inputs and enables users to study long term impacts. Streamflow calibration in the upper and lower reaches of the catchment showed good performance with R^2 of 0.64 and 0.58, respectively. The SWAT module for predicting microorganism loads and concentrations in the river was used. The main faecal sources in the uMsunduzi catchment can be summarised as: wastewater treatment plant (WWTP), broken sewers in the urban area, and faecal droppings from grazing livestock. The microorganism loads from these sources were described in SWAT using data from different local water authorities and stakeholders. With respect to *E. coli*, the output from SWAT was compared to observed data from four points within the catchment representing upper rural, upper urban, lower urban, and lower rural parts. The output from the SWAT model showed slightly low variability, however, the trend in the SWAT model simulations followed the observed data patterns in most subbasins. The trend with *Cryptosporidium* was such that concentrations are higher downstream the WWTP than upstream, though insufficient data exists to compare the model *Cryptosporidium* output with observed data. Overall, the model microbial output showed that in rural areas, animals contribute more to pathogen loads than human

sources. Human sources were more prominent in urban areas owing to the major contributions from wastewater infrastructure. The microbial output data from the SWAT model were used as input for quantitative microbial risk assessment (QMRA). Considering that not all *E. coli* are pathogenic, 8% of *E. coli* was assumed as pathogenic following various studies. The exposure routes investigated were direct ingestion of the uMsunduzi River water during recreational swimming, canoeing training, and drinking. The exposed population was categorised as children (<18 years old) and adults (>18 years old). The probability of infection for most users exceeds the acceptable level for drinking and recreation as outlined in the South African water quality guidelines and by the World Health Organisation (WHO).

The results of this study can be used as a baseline to assess the economic and health implications of different management plans, resulting in better-informed, cost-effective, and impactful decision-making.