

**IDENTIFYING POLLUTION SOURCES IN THE KELANI RIVER
BASIN, SRI LANKA: AN INTEGRATION OF MACHINE
LEARNING AND PROCESS-BASED MODELLING
APPROACHES**

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Degree of Master of Science

Department of Civil Engineering

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Sri Lanka

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Thesis submitted in partial fulfillment of the requirements for the degree
Master of Science

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23-12-2024

Date

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ABSTRACT

Water pollution poses a significant challenge globally, especially in developing nations like Sri Lanka. The Central Environmental Authority has identified the Kelani River as the most polluted river in the country. This study utilized 17 water quality parameters varying across 17 water quality monitoring stations along the Kelani River for the 2016–2020 period to assess the pollution level and identify the pollution sources in the Kelani River Basin (KRB). Initially, unsupervised machine learning methods were used to identify spatial and seasonal water quality variations. Factor analysis was used to generate Latent Variables (LV) considering the total variance in the dataset. Then two pollution indices were developed: the Kelani River Basin-Industrial Pollution Index (KRB-IPI) and the Kelani River Basin-Sewage Pollution Index (KRB-SPI) to quantify the pollution and to identify pollution sources in the basin. The KRB-IPI and KRB-SPI were validated through a Long Short-Term Memory Artificial Neural Network (LSTM ANN). Finally, a pollutant transport model was developed to assess the impact of these sources on the main river by simulating the Iron (Fe) transport in the Lower Kelani River Basin (LKRB). The development of the pollutant transport model began with the creation of an HEC-HMS model to generate sub-catchment hydrographs, which were calibrated (2016–2017) and validated (2018–2020) against observed discharge at Hanwella and Nagalagam Street streamflow stations. Hybrid modelling techniques further reduced errors in the generated hydrographs. The error-corrected hydrographs and observed streamflow were used to develop an HEC-RAS model for the Kelani River, which was calibrated and validated with observed data. The flow, velocity, and water depth parameters from the HEC-RAS model were used to develop a Water Quality Analysis Simulation Program (WASP) model, calibrated and validated with measured Fe records.

The FA generated five LVs, accounting for 77% of the total variance in the dataset. The spatial variation analysis highlighted that the stations near industrial zones and urbanized areas showed higher water quality variations. Seasonal variation analysis revealed strong relationships between water quality and monsoonal patterns. The KRB-IPI identified Cadmium, Iron (Fe), and Zinc as the main industrial pollutants, while the KRB-SPI identified Dissolved Oxygen, Total Coliform, and Chemical Oxygen Demand as the main parameters influencing sewage pollution. The developed KRB-IPI and KRB-SPI were validated through an LSTM ANN model with a Nash–Sutcliffe Efficiency (NSE) value of 0.98 and a Root Mean Squared Error (RMSE) value of 0.81 for KRB-IPI and an NSE value of 0.99 and an RMSE value of 1.83 for KRB-SPI. The KRB-IPI identified Kollonnawa Ela, Raggahawatte Ela, Maha Ela, Pusseli Oya, and Pugoda Ela as potential industrial pollution sources. Similarly, the KRB-SPI identified Victoria, Kollonnawa, Raggahawatte Ela, Maha Ela, Pugoda Ela, and Seethawake as potential sewage pollution sources. The WASP model was calibrated and validated with observed Fe records at Victoria station (Root squared error (R^2) = 0.893 in calibration and R^2 = 0.768 in validation) and Hanwella station (R^2 = 0.851 in calibration and R^2 = 0.757 in validation). The pollutant transport model identified Pugoda Ela station as having the highest impact on the water pollution of the Kelani River with a Mean Absolute Percentage Error (MAPE) of 16.21%. Maha Ela and Pusseli Oya were also confirmed as pollutant sources with MAPE values of 10.09% and 8.27%, respectively. The results suggest that the proposed method can effectively identify and quantify pollution in source catchments, offering a scalable methodology for other river basins to ensure sustainable water resource management.

Keywords: HEC-HMS, HEC-RAS, Hybrid Modelling, WASP, Water Pollution

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LIST OF ABBREVIATIONS

CA – Cluster Analysis

CEA – Central Environmental Authority

FA – Factor Analysis

HCA – Hierarchical Cluster Analysis

HEC-HMS – Hydrologic Engineering Centre-Hydrologic Modelling System

HEC-RAS – Hydrologic Engineering Centre-River Analysis System

IM1 – First Intermonsoon

IM2 – Second Intermonsoon

KRB – Kelani River Basin

KRB-IPI – Kelani River Basin-Industrial Pollution Index

KRB-SPI – Kelani River Basin-Sewage Pollution Index

LKRB – Lower Kelani River Basin

MICE - Multiple Imputation by Chained Equations

NEM – Northeast Monsoon

SOM – Self-Organizing Maps

SWM – Southwest Monsoon

WASP – Water Quality Analysis Simulation Program

WHO – World Health Organization