



FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF WATER RESOURCES ENGINEERING

**APPLICATION OF DATA DRIVEN MODELING IN ASSESSING THE EFFECT OF
INFLUENT VARIABILITY AND WEATHER CHANGES ON THE PERFORMANCE OF
TORORO WASTEWATER STABILIZATION PONDS**

BY

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*A final year research project report submitted to the department of water resources engineering
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ABSTRACT

This study investigated the Tororo Wastewater Treatment Plant's stabilization ponds under varying climatic conditions and increasing influent loads, aiming to guide sustainable water management in alignment with Uganda's Vision 2040 and SDGs 6, 11, and 13. Methodologically, historical data (2014–2024) covering influent rates, wastewater characteristics, and key climate variables were analyzed using descriptive statistics, Principal Component Analysis (PCA), Cluster Analysis (CA), and regression analyses to characterize pond performance and identify dominant influencing factors. Subsequently, three data-driven predictive models Multivariate Regression, Artificial Neural Networks (ANN), and a Hybrid GRU-LSTM Recurrent Neural Network (RNN) were developed and tested using normalized and partitioned datasets. An LSTM-based forecasting model was also developed to project future influent parameters.

Key results showed that Facultative Ponds 1 and 2 frequently experienced negative TSS removal efficiency and moderate BOD/COD reductions (19–26%). In contrast, the Maturation Pond demonstrated more stable TSS reduction (around 26.9%) and slightly higher BOD removal (up to 37.4%), but struggled with ammonia removal efficiency. All ponds achieved consistently high fecal coliform attenuation ($\geq 89\%$). The Hybrid GRU-LSTM model delivered superior predictive accuracy for effluent parameters (R^2 up to 0.97 for BOD, COD, TSS), outperforming other models by effectively capturing temporal dependencies. Feeding forecasted influent parameters into this Hybrid GRU-LSTM model achieved robust accuracy for future effluent predictions (overall $R^2 \approx 0.81$).

These findings highlight that data-driven forecasting, coupled with targeted operational interventions (e.g., optimized sludge management, improved pond hydraulics), can enhance stabilization pond resilience. This approach ensures more reliable wastewater treatment and supports sustainable development goals in rapidly urbanizing settings.

Keywords: Wastewater Stabilization Ponds, Data-Driven Modeling, weather Change, Influent Variability, Predictive Modeling, Hybrid GRU-LSTM, Uganda

DECLARATION

I BAKHITA EVELINE, registration number BU/UP/2021/0243, declare that the work in this research report is my original work and has not been presented to any higher institution of learning for any academic award.

SIGNATURE:

A small, handwritten signature in blue ink, appearing to read 'B. Eveline', is placed on a white rectangular background.

DATE: 16th May, 2025

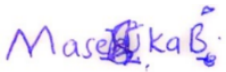
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APPROVAL

I hereby certify that this project is original research report of BAKHITA EVELINE, BU/UP/2021/0243. It has been done under my supervision and is ready for submission to the department of water resources engineering.

SUPERVISOR: MASERUKA S BENDICTO

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DATE: 16th May, 2025

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DEDICATION

I dedicate this final year project proposal to my beloved family my mother Alma Lalar, my brother Otto Julius and my sisters Amal Grace and Hidah Sidah, for their unwavering love, support, and encouragement have been the driving force behind my academic pursuits may the almighty God bless the abundantly.

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LIST OF ACRONYMS

ANN	Artificial neural network
ANOVA	Analysis of Variance
BOD	Biochemical Oxygen Demand
CNN	Convolutional Neural Network
COD	Chemical Oxygen Demand
EC	Electrical Conductivity
KNN	K-Nearest Neighbor
MR	Multivariate regression
PCA	Principal Component Analysis
RNN	Recurrent neural network
SOM	Self-Organizing Map
TSS	Total Suspended Solids
WSP	Wastewater stabilization ponds

LIST OF ABBREVIATIONS

E.g.	Example
E. coli	Escherichia coli
EPA	Environmental Protection Agency
HRT	Hydraulic Retention Time
i.e.	That is to Say
PH	Potential of Hydrogen
RMSE	Root Mean Square Error
R^2	Coefficient of Determination
MSE	Mean Squared Error
MAPE	Mean Absolute Percentage Error
NWSC	National Water and Sewerage Corporation
SDG	Standard Development Goal
UN	United Nation

6.Recommendations

Future efforts should focus on: (1) enhancing monitoring of key influent parameters (COD_{in}, BOD_{in}, FC_{in}); (2) integrating validated data-driven models into operational decision-support systems for WSPs; (3) developing climate-resilient WSP designs considering compound weather events; and (4) advancing research into improved pH prediction, incorporating more comprehensive input features for nutrient modeling (including pond design kinematics and microbial activity indicators), and exploring real-time model implementation with adaptive learning capabilities.

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