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Background

Wastewater treatment (WWT) process aims to achieve a treated effluent and sludge quality that is environmentally safe for disposal/or reuse (Fezzi, 2015). Waste Stabilisation Ponds (WSP) are commonly recommended treatment systems used in semi-arid developing countries including Malawi (Khodadadi, *et al.,* 2016). Mainly, WSPs are designed to remove organic load which is normally measured as Biochemical Oxygen Demand (BOD5) (Khodadadi, *et al.,* 2016).

In Malawi wastewater generation has increased due to increase in population, urbanisation and industrialisation (Msilimba & Wanda, 2014). This has led to the establishment of stringent environmental regulations to ensure that water bodies are protected by reducing point source pollution. Key policies and legislation guiding management and operations of wastewater in Malawi include Waterworks Act 1995, Water Resources Act 2013, National Sanitation Policy 2008, Local government Act, Public Health Act and Malawi Bureau of Standards.

Despite the existence of these regulatory frameworks in Malawi, there is limited and non-existent effluent treatment (Ngoma, *et al.,* 2020). In addition, there is lack of comprehensive and regular monitoring of wastewater treatment plants and surface water quality by the responsible authorities due to limited staff, inadequate funding and inadequate laboratory facilities (Wanda, *et al.,* 2016).

The operations of few working WWT facilities in Malawi including Kauma STP, only depend on the conventional experimental approach to determine the quality of the treated effluent water before discharge or reuse. However, this method is time consuming. For instance, it requires 5 days to measure Biochemical Oxygen Demand (BOD), and their determination procedures involve the use of several dangerous chemicals (Baki, *et al.,* 2019). Further, laboratory tests also require the engagement of experienced professionals to obtain high-quality results (Baki, *et al.,* 2019). Optimal WWTP operation and control can be achieved by the development of a robust mathematical tool that enables the prediction of the quality of the treated effluent based on past observation of certain key parameters (Hassen & Asmare, 2019). Mathematical models are important for improving its treatment efficiency and thus the quality of the effluent released into receiving waterbody (Hassen & Asmare, 2019). Models can help the operator to predict the performance of the plant in order to take cost effective and timely remedial actions that would ensure consistent treatment efficiency and meeting discharge consents (Rustum, 2009).

This study intends to apply artificial intelligence techniques to model Kauma wastewater treatment process. Different algorithms namely, Kohenen Self Organising Map, Backpropagation Artificial Neural Network (BPANN) and Adaptive Fuzzy Inference Systems (ANFIS) will be applied to develop different models for predicting BOD5 for Kauma WSP.

It is anticipated that this study will improve plant operation and control through the application of Artificial Intelligence models. This will result in into improvement of effluent water quality thereby contributing to SDG 6.3 target. The models will also reduce the need for chemicals which will, in turn, save operational cost for Kauma WSP.

Materials and methods

Study area

This study will be conducted at Kauma Sewage Treatment plant (STP) located in Lilongwe, capital city of Malawi. The plant was constructed in 1996 with a design capacity of 6100m3/day. Current population for Lilongwe city is estimated to be 989318. Only 5% of this population are connected to the sewer system while 95% rely on onsite sanitation. Effluents of Kauma STP are discharged into Lilongwe river which is the biggest river within the city.

Research design and sampling

The study will adopt experimental (quantitative) research design. The minimum sample size will be 96 data sets for each parameter namely flow rate, pH, Temperature, BOD5, Chemical Oxygen Demand, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Electrical Conductivity (EC) Turbidity, Nitrates, Total Phosphorus, Total Nitrogen, Dissolved Oxygen (DO), Mercury, Cadmium, Lead and Feacal coliform. Sampling location for these parameters will be at the entry point before the screen and discharge location.

Data collection

Both primary data and secondary data will be collected. Primary data will be collected for six weeks on daily basis, and all parameters will be determined in accordance with American Public and Health Association 2017. Secondary data will emanate from desk review and Kauma STP Laboratory.

Modelling approaches

Models will be developed in four main stages namely: Data processing, choosing algorithm in MatLab programming language, Selection model structure and performing numerical analysis. Data processing will involve generating descriptive statistics (Minimum value, maximum value, mean and standard deviation correlation Matrix) for all variables. Outliers that will be identified through box whisker plot and all missing values will be replaced Not a Number "NAN" to meet MatLab Requrements. The next step will be choosing algorithm in Matlab Programming language (R2020b). Kohonen self-organising map, Backpropagation Neural Network and Adaptive fuzzy Inference Systems (ANFIS) are algorithms that will be used. This will be followed by constructing a model structure in MatLab. Here the model inputs will be chosen based on their correlation to BOD5. Numerical analysis will be the last step for developing these models. At this stage, training testing, model evaluation and hypothesis testing will be done. Correlation coefficient (R), Mean Square Error (MSE) and Average Absolute Error (AAE) will be used to evaluate the models. Paired T-Test will be used to test whether there is significant difference between observed values and simulated (predicted) values in Matlab R2020b.

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