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Prediction of dissolved oxygen and nitrate concentration in activated sludge wastewater treatment using artificial neural network

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Abstract

Plays a significant role in returning safe and clean water back to its source, wastewater treatment plant (WWTP) need to operate efficiently despite challenges in energy consumption and stringent effluent standards set by the authority. Modeling the activated sludge process (ASP) of WWTP is essential for better understanding of the system, safety, dynamic prediction, control, and optimization of the plant The mechanistic model is too complex causing it difficult to be applied directly to controller design making a data-driven model that is known for its simplicity, and high prediction accuracy is a desirable choice. The aim of this study is to determine a reliable data-driven model for a WWTP by identification of the relevant input variables for the prediction of dissolved oxygen concentration and nitrate concentration in the neural network model. This is essential because the ASP WWTP contains large variations of parameters and is highly nonlinear. In this study, the important parameters for both dissolved oxygen and nitrate have been successfully identified. The simulation results using the proposed input combinations show that the neural network model able to predict both controlled variables closely. Additionally, the selected combination is with the lowest mean-square error and highest regression percentage.

Keywords: *Activated sludge; Data-driven model; Neural network model; Nonlinear; Wastewater treatment plant.*

1. Introduction

Clean water is an essential resource for human beings and the environment all over the world. WWTP abet in protecting the public health by preserving water resources and protecting the environment for a sustainable future. More stringent effluent standards established for WWTP towards a better environment. The biggest challenge faced by the WWTP industry is to come up with solutions that comply with the new standards and is economically viable.

In recent years, advanced control systems [1] – [5] have succeeded as a sensible solution to the problem above with its approach to achieve better effluent quality and lower energy consumption compared to conventional PID controller. Model predictive control (MPC) and adaptive model control are examples of advanced control systems. The main issue in advanced control systems, for example, MPC is the requirement of a good predictive model to determine the future response of the plant. The striving in producing a good predictive control arises as the biological process of treating the wastewater is highly complex, difficult to understand and unpredictable. Also, issues of nonlinearity, influent variation and large disturbances are impeding the modeling of the ASP. The available models, i.e. Activated Sludge Model (ASM) families such as ASM1, ASM2, ASM2d, and ASM3 are mathematical models developed by the International Water Association (IWA) have aided in giving the insight and information about the ASP. However, these models are complicated structurally (with a considerable number of parameters used to describe the nonlinearity and uncertainty of the process). Thus, making it grueling to be applied to control purpose. Still, papers are utilizing modified or simplified ASM1 model [6] used as the predictive model to their control system. The data-driven model, precisely a neural network model, has recently captured a considerable amount of interests from researchers because of its simplicity and prominent level of prediction accuracy. The neural network model derived from sets of real data from the WWTP.

There are several papers from since last decade and even recently which have researched modeling of the ASP directed on an intelligent model such as a fuzzy model, the neural network model [1], [6] – [10] or hybrid model [7] – [11]. Nevertheless, other modeling techniques are still evolving such as ODE-PDE model [12], [13], and a black-box model [14] – [16]. However, from the observation, the author sees that most modeling of ASP was carried out to predict the effluent quality [17] – [21] of WWTP such as chemical oxygen demand (COD), total suspended solids (TSS), and biological oxygen demand (BOD).

The key objective of this article is to carry out modeling of ASP to predict dissolved oxygen concentration and nitrate concentration which are the controlled variables used in the Benchmark Simulation Model No. 1 (BSM1) protocol. There are very few papers are found working on modeling of either dissolved oxygen concentration [22] or nitrate concentration [23].

It was mentioned that it is crucial to identify the important parameters for modeling both concentrations as the bioprocess model in BSM1 is described using ASM1. As observed from [27], ASM1