MODELING STUDIES
FOR THE DETERMINATION OF
COMPLETELY MIXED ACTIVATED SLUDGE
REACTOR VOLUME: STEADY-STATE,
EMPIRICAL AND ANN APPLICATIONS

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Abstract: This paper presents an empirical model and a three-layer (7:11:1) artificial neural network (ANN) approach for the determination of completely mixed activated sludge reactor volume (CMASRV). CMASRV values were estimated by a new mathematical formulation and a three-layer ANN model for 1,000 different artificial scenarios given in a wide range of seven biological variables. The predicted results obtained from each stochastic approach were compared with the well-known steady state volume model based on mass balance equations. The computational analysis showed that the proposed empirical model and ANN outputs were obviously in agreement with the steady-state volume model and all the predictions proved to be satisfactory with a correlation coefficient of about 0.9989 and 1, respectively. The maximum volume deviations from the steady-state volume equation were recorded as only 7.17% and 6.89% for the proposed model and ANN outputs respectively. In addition to volume comparison, waste sludge mass flow rates ($P_X$), food to mass ratios ($F/M$), hydraulic retention times (HRTs), volumetric organic loads ($L_V$) and oxygen requirements (ORs) were also compared for each model, and significant points of proposed approaches were evaluated.

Key words: Activated sludge, completely mixed reactor, steady-state model, empirical model, artificial neural network

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1. Introduction

The activated sludge process is the most generally applied biological wastewater treatment method. In the activated sludge process, a bacterial biomass suspension is responsible for the removal of pollutants. Depending on the design and the specific application, an activated sludge wastewater treatment plant can achieve removal of biological nitrogen and biological phosphorus, besides removal of organic carbon substances [1]. The principle in activated sludge plants is the following: a mass of activated sludge consisting largely of bacteria is kept moving in water by stirring or aeration [2]. In the process, large quantities of air are bubbled through wastewaters that contain dissolved organic substances in open aeration tanks. Oxygen is required by bacteria and other types of microorganisms present in the system to live, grow, and multiply in order to consume the dissolved organic “food”, or pollutants in the waste.

The activated sludge process has been employed extensively throughout the world in its conventional form and modified forms, all of which are capable of meeting secondary treatment effluent limits. Step aeration, contact stabilization, completely mixed activated sludge, extended aeration and closed-loop reactor (also known as oxidation ditch) can be included in modified forms of the conventional activated sludge process. Aeration time ranges between 3 and 6 hours. Recirculation ratios in a completely-mixed system will range from 50 to 150% [3]. The term “completely mixed reactor” usually refers to a continuously stirred tank reactor (CSTR) concept, a simplified representation that is often used to represent activated sludge tanks. A CSTR has one input, and indeed the concentrations are assumed to be homogeneous throughout the tank due to vigorous mixing, but certainly not because wastewater and sludge are introduced uniformly over the tank.

In order to achieve an efficient biological treatment, the most appropriate process design should be performed. Biological variables used in the design should be representative for the activated sludge process as far as possible. Activated sludge processes are based on many projection criteria, such as wastewater flow rate \( Q \), mixed liquor volatile suspended solids (MLVSS) concentration, biochemical oxygen demand (BOD\(_5\)) load, hydraulic retention time (HRT), sludge age \( \theta_C \), oxygen requirement (OR) and other some different biological variables related to the process.

Modeling is a valuable tool in both design and operation of biological treatment plants. In addition, modeling of wastewater treatment plants can also be used for process optimization and testing of control strategies in order to meet effluent quality requirements at a reasonable cost. Hence, modeling helps to develop a better understanding of the treatment processes and provides a significant potential for solving operational problems as well as reducing operational cost in biological wastewater treatment process [4]. Moreover, model results can be evaluated for different operating data before transferring the concepts to a full-scale plant. The volume of an activated sludge reactor can be calculated by using different mathematical models in terms of biological variables. It should be noted that some of the kinetic coefficients presented in literature differ extremely from each other. Hence, an appropriate data set depending on ranges of input biological variables should be