Chapter 11
Adaptive Network Based Fuzzy Interference System (ANFIS) Modeling of an Anaerobic Wastewater Treatment Process

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ABSTRACT

The successful operation of a high-rate anaerobic reactor, up flow anaerobic sludge blanket (UASB) reactor depends on the prevailing physico-chemical and biological conditions during its operation. The wastewater characteristics and composition, the hydrodynamics of the process, and microbial activity are critical for achieving long term, optimal reactor performance. Modeling UASBs can be beneficial for design, prediction, and control purposes. This chapter provides sufficient background information on the different biochemical stages of anaerobic treatment, viz., hydrolysis of biodegradable solids, acetogenesis and methanogenesis, the working of a UASB reactor, and some insight into mechanistic modeling of UASBs. The application of neural networks, and a conceptual neural fuzzy model, i.e., adaptive network based fuzzy inference system (ANFIS), to model the performance of UASB is systematically outlined in this chapter.

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INTRODUCTION

Anaerobic Wastewater Treatment Processes

Rapid urbanization and the emergence of new manufacturing industries have not only contributed to the decline in environmental quality, but have also deteriorated water quality leading to severe water pollution. Effluents from industrial unit operations (example: distillery effluents from sugar cane industry) are often characterized by high organic content, nutrients in the form of nitrogen, phosphorous, and potassium, that can pose a significacnt threat to the environment, if discharged untreated (Turkdogan-Aydinol and Yetilmezsoy, 2010). Water quality (municipal and industrial) is generally estimated by measuring different physico-chemical and biological parameters; *viz.,* as, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total organic content (TOC), total dissolved solids (TDS), total suspended solids (TDS), etc, among others, depending on the wastewater composition and characteristics (Mullai et al., 2011). Both aerobic and anaerobic treatment systems have been tested at the industrial scale for treating medium and high strength wastewater. Typical examples are activated sludge process (ASP), trickling filters (TF), oxidation ponds, upflow anaerobic sludge blanket reactor (UASB), and sequencing batch reactor (SBR).

For anaerobic treatment systems to be efficient, it has to be fed with low strength wastewater, where typical chemical oxygen demand values are less than 1000 mg/L (Mrowiec and Suschka, 2010). Besides, these systems are well suited for process industries like food processing, breweries, soft drink production facilities, pulp and paper manufacturing, fish processing, and textile industries. According to Nykova et al. (2002), the positive effects of using anaerobic treatment systems include; removal of higher organic loading, low sludge production, high pathogen removal, methane gas production, and low energy consumption.

Lyberatos and Skiadas (1999) have highlighted the operational advantages of using high-rate (high performance) anaerobic reactors; (i) operation at high solids retention times (SRTs), (ii) possibility to operate at very low hydraulic retention times (HRTs), (iii) simple design, (iv) efficient heat and mass transfer, (v) small foot prints, (vi) robustness to handle transient operations, such as unexpected loading rates, and (vii) biogas generation secures good mixing characteristics. The basic mechanism of wastewater treatment in an anaerobic system consists of several independent, yet sequential and parallel biological reactions, during which the products from one group of microorganisms serve as the substrates for the next, resulting in transformation of organic matter mainly into a mixture of methane and carbon dioxide. The four stages of anaerobic digestion are as follows; hydrolysis/liquefaction, acidogenesis, acetogenesis, and methanogenesis (McMahon et al., 2001). There is also a significant amount of interest in this topic (anaerobic systems), such as plant-biomass-fed digesters, since the produced methane is a useful source of energy (Kaparaju et al., 2008).

Based on their research experiences using extensive laboratory and pilot scale studies, several authors have proposed the basic biochemical stages in anaerobic digestion. According to Kleinstreuer and Powegha (1982), the process involves the hydrolysis of biodegradable solids, acetogenesis and methanogenesis (Figure 1a). Moletta et al. (1986) showed an acetogenesis step that forms acetate from glucose, and were inhibited by un-dissociated acetic acid (Figure 1b). Both slow and a fast hydrolysis steps were proposed by Smith et al. (1988), that also includes acidogenesis of the soluble intermediates and methanogenesis (Figure 1c).

Upflow Anaerobic Sludge Blanket (UASB) Reactor

Upflow anaerobic sludge blanket (UASB) is a methane-producing anaerobic digester which is