Chapter 4
ANNs for Identifying Shock Loads in Continuously Operated Biofilters:
Application to Biological Waste Gas Treatment

Eldon R. Rene
University of La Coruña, Spain

M. Estefanía López
University of La Coruña, Spain

Hung Suck Park
University of Ulsan, South Korea

D. V. S. Murthy
Broward College, USA

T. Swaminathan
Indian Institute of Technology Madras, India

ABSTRACT

Among the different waste gas treatment techniques developed to eliminate odorous and toxic pollutants from air, biological techniques have emerged as an effective, reliable, eco-friendly, simple, and economical option. Biological waste gas treatment systems such as biofilters are commonly used in industrial complexes to handle emissions at high gas flow rates and low pollutant concentrations (<5 g/m³). However, from a practical view-point, variation in concentrations and gas flow rates are common to any industrial emission, and it is a pre-requisite to simulate these conditions (shock loads) at the laboratory scale. This chapter provides sufficient theoretical background information on the different waste gas treatment systems, literature review on shock loads in biofilters, and the different steady and transient state models developed in the field of biofiltration. A fundamental overview of artificial neural networks and the different steps of the modeling process are also presented.

DOI: 10.4018/978-1-4666-0294-6.ch004

BACKGROUND

Experiments were performed in three lab-scale (identical) biofilters inoculated with mixed culture from a wastewater treatment plant. Benzene, toluene and xylene were chosen as the model pollutants for this study. The maximum elimination capacity (EC_{max}) in the biofilter ranged between 52 and 107 $g/m^3.h$ for benzene, toluene or xylene, respectively, under steady state conditions. Shock loading tests were performed in these biofilters at two different gas flow rates (0.036 and 0.06 m^3/h), and by varying the concentrations of individual pollutants, from low to medium (or) high levels, almost instantaneously. The responses of the biofilters were evaluated by their removal efficiency profiles. Artificial neural networks (ANNs) was used as a modeling tool to map the transient or shock loading patterns in these biofilters, owing to their significant advantages over other non-linear modeling paradigms. Through proper training, and optimization of different network parameters, the developed model (architecture: 2-6-1) was able to identify the variations of biofilter performance caused by the unexpected shock loads. Besides, with data from real gaseous effluents, another multi layered perceptron (MLP) with the architecture 3-4-2 was developed to predict the performance of a biofilter that was able to successfully handle mixtures of waste gases containing both benzene and toluene.

INTRODUCTION

Volatile Organic Compounds (VOCs)

The issue of air pollution has been a topic of great importance, and one of the most urgent environmental problems to be solved worldwide. Scientific research and technological advancements have contributed tremendously to understand the deleterious effects of air pollutants on human beings and the environment. Over the past few years, several physical and chemical technologies have been developed to remove a wide variety of air pollutants that include; NO_x, SO_x, carbon monoxide, hydrogen sulfide, ammonia, mercaptans, methane, volatile hydrocarbons and numerous volatile organic compounds (VOCs), amongst others, from both natural and industrial sources. According to the United States Environmental Protection Agency (US-EPA), VOC can be defined as ``*any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions*``. Typical products that has the ability to release these VOCs include; paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions. Among the list of different chemicals mentioned in the Clean Air Act of 1990 (US-EPA), benzene, toluene and xylene (collectively called as ``BTX``) are more commonly found in emissions from petrochemical and pharmaceutical industries. The health effects of these VOCs have been well documented in the literature. For example, chronic poisoning due to toluene inhalation occurs at about 200-400 mg/m^3, while impairment of reaction time was observed in volunteers exposed to 870 mg/m^3 of xylene vapours for 3 hours (WHO, 1986). The physical and chemical properties of BTX compounds are shown in Table 1.

Biological Treatment of Waste Gases

Treatment of VOCs from industrial sources, such as emissions from point sources, is a relatively new application of bioreactor technologies. Biological waste gas treatment systems have gained support as an effective, reliable, eco-friendly, simple and economical option in comparison to the different physico-chemical VOC removal technologies