Chapter 5
Fundamentals of the Biological Processes for Nitrogen Removal

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ABSTRACT

In this chapter the fundamental aspects involved in biological treatment processes applied for the removal of nitrogen from wastewaters are described. A comprehensive review of the literature is provided including kinetic, microbiological and biochemical aspects of nitrification, denitrification and anammox, as well as key operational parameters affecting the processes. This information is relevant for designing wastewater treatment processes applied for the removal of nitrogen from wastewaters. The information is also essential for predicting and controlling the performance of these treatment processes.

INTRODUCTION

Excess nitrogen discharged from industrial wastewaters represents a threat to water reservoirs as it promotes several environmental problems. In addition, nitrogen pollution could induce adverse effects on human health. Besides the nitrogen pollution linked to intensive agriculture and combustion of fossil fuels, an important source of this contamination comes from industries demanding different nitrogenous compounds. For instance, NH_3 is used as a raw material to create multiple products, such as nylon, plastics, resins, glues, melamine, animal/fish/shrimp feed supplements, and explosives. A recent global assessment has pointed out three major environmental problems caused by nitrogen pollution in aquatic ecosystems:

1. It can drastically decrease the pH of freshwater ecosystems without much acid-neutralizing capacity, leading to acidification of these water bodies;

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2. It can stimulate or enhance the development, maintenance and proliferation of primary producers, resulting in eutrophication of aquatic ecosystems; and
3. It can also impair the ability of aquatic animals to survive, grow and reproduce as a consequence of direct toxicity of nitrogenous compounds (Cervantes 2009).

Additionally, nitrogen pollution can have important economic effects in different sectors. For instance, human sickness and death, resulting directly (*e.g.* ingested nitrate and nitrite from polluted drinking water) or indirectly (*e.g.* aerosol exposure to algal toxins, consumption of contaminated seafood causing poisoning syndromes) from nitrogen pollution, can have high economical expenses because of lost wages and work days, and because of medical treatment and investigation (Camargo & Alonso, 2006). Many countries have strictly regulated the discharge of nitrogen-rich wastewaters into aquatic ecosystems to prevent these environmental, economic and public health concerns.

Biological processes represent sustainable technologies to remove nitrogen from industrial wastewaters. This chapter describes the fundamental aspects of biological processes involved in nitrogen removal. Kinetic, microbiological and biochemical aspects will be described as well as key operational parameters affecting the processes. The chapter will firstly describe aspects related to nitrification, followed by denitrification and anaerobic ammonium oxidation (anammox).

NITRIFICATION

Ammonia removal from wastewaters can be achieved by physicochemical or biological processes. The first alternative is fast and efficient, but may not be sustainable, as the pollutant is usually transferred from one place to another, or because the treated water is not attractive due to increased saline concentration, bad odor, or extreme end pH values. Most typical physicochemical methods are stripping, electrochemical removal, precipitation or a combination of them (Bonmati & Floats, 2003; Chen, 2004). On the other hand, biological ammonia removal is usually carried out in two steps, one aerobic and the other anoxic. The former is known as nitrification, and the latter is referred to as denitrification.

Nitrification was firstly described by Winogradski (1890), who isolated and characterized *Nitrosomonas* and *Nitrobacter* species from soil. From the microbiological and physiological points of view, nitrification has deeply been described by Prosser (1989) and Francis et al. (2007). Nitrification is a key process intensively interacting with the carbon, nitrogen, and sulfur cycles. Nitrification is a catabolic pathway where ammonia is oxidized to nitrate. It is known as a respiratory process, which yields energy for microbial growth. It is important to note that the produced energy throughout the catabolism is not always used for microbial growth, as other cell functions, such as maintenance, may consume it, or it may be dissipated to the environment as heat. Under controlled conditions, ammonia can completely be oxidized to nitrate, but the produced energy not necessarily be utilized for biosynthetic reactions. In this case, the energy produced is dissipated and, therefore, nitrification turns into an energetically dissimilative process where biomass production is negligible (Texier & Gomez, 2002, 2007). This fact is relevance in wastewater treatment systems, which minimize sludge generation while achieving nitrogen removal.

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