# Chapter 10
# Anammox Process: Technologies and Application to Industrial Effluents

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## ABSTRACT

*Application of anammox based processes is nowadays an efficient way to remove nitrogen from wastewaters, being good alternative to the conventional nitrification-denitrification process. This chapter reviews the possible configurations to apply the anammox process, being special attention to the previous partial nitritation, necessary to obtain the adequate substrates for anammox bacteria. Furthermore a description of the main technologies developed and patented by different companies was performed, with focus on the advantages and bottlenecks of them. These technologies are classified in the chapter based on the type of biomass: suspended, granular and biofilm. Also a review is presented for the industrial applications (food industry, agricultural wastes, landfill leachates, electronic industry, etc.), taking into account full scale experiences and laboratory results, as well as microbiology aspects respect to the anammox bacteria genera involved. Finally the possibility to couple nitrogen removal, by anammox, with phosphorus recovery, by struvite precipitation, is also evaluated.*

## INTRODUCTION

The anaerobic ammonium oxidation (anammox) process is the anaerobic oxidation of ammonium (van de Graaf, de Bruijn, Robertson, Jetten, & Kuenen, 1996) using nitrite as electron acceptor and carbonate for cell biosynthesis, according to the stoichiometry described by (Strous, Heijnen, Kuenen, & Jetten,

DOI: 10.4018/978-1-5225-1037-6.ch010

1998) (Equation 1) and recalculated latter by a kinetic characterization experiment with a suspended anammox culture by (Lotti, Kleerebezem, Lubello, & van Loosdrecht, 2014) (Equation 2):

$$NH_4^+ + 1.32\ NO_2^- + 0.066\ HCO_3^- + 0.13H^+ \rightarrow 1.02\ N_2 + 0.26NO_3^- + 0.066\ CH_2O_{0.5}N_{0.15} + 2.03\ H_2O \quad (1)$$

$$NH_4^+ + 1.146\ NO_2^- + 0.071\ HCO_3^- + 0.057H^+ \rightarrow 0.986\ N_2 + 0.161\ NO_3^- + 0.071\ CH_{1.74}O_{0.31}N_{0.20} + 2.002\ H_2O \quad (2)$$

This reaction is carried out by anammox bacteria, belonging to Planctomycetes phylum, including the genera *Brocadia*, *Kuenenia*, *Anammoxoglobus*, *Jettenia* and *Scalindua* (Jetten et al., 2009). According to Equation 1 and Equation 2, in order to treat ammonia rich effluents with the anammox process, half of the incoming nitrogen needs to be oxidized to nitrite. The latter process is called nitritation (Equation 3), and it is performed by the ammonia oxidizing bacteria (AOB).

$$NH_4^+ + 0.0743\ HCO_3^- + 1.404\ O_2 \rightarrow 0.985\ NO_2^- + 0.0149\ C_5H_7O_2N + 1.911\ H^+ + 1.03\ H_2O \quad (3)$$

The fully autotrophic nitrogen removal from wastewater can be achieved by combining the appropriate ratio of nitritation (partial nitritation) with the anammox process, given the overall reaction as (Equation 4):

$$NH_4^+ + 0.804\ O_2 + 0.071\ HCO_3^- \rightarrow 0.111\ NO_3^- + 0.436\ N_2 + 0.009\ C_5H_7O_2N + 0.028\ CH_2O_{0.5}N_{0.15} + 1.038\ H^+ + 1.46\ H_2O \quad (4)$$

Compared to conventional nitrification-denitrification processes, the fully autotrophic nitrogen removal allows for the saving of 100% organic matter, for a potential biogas production by anaerobic digestion (Wett, 2007), and the reduction of operational costs if the effluent COD/N ratio is lower than 5 g/g (Fux & Siegrist, 2004). Also, oxygen requirements are reduced around 60% (Ahn, 2006), sludge production around 90% (Vazquez-Padin et al., 2014) and $N_2O$ production around 83% (Morales et al., 2015b) of the values required for the conventional processes. This costs reduction makes the technologies based on the anammox process attractive for the industrial sector.

However, some questions have to be taken into account like the complexity of wastewater from industrial origin which makes its treatment more difficult. Furthermore, the presence of toxic compounds and the potential lack of nutrients and trace elements necessary for the growth of microorganisms are further factors to be considered.

Up to date, the anammox based process has been successfully applied for the treatment of different types of wastewater with high ammonium content such as landfill leachate, manure or food industry effluents. However, many other industrial sectors may benefit from the application of this technology and research is ongoing to broaden the field of applicability especially focusing on those industrial effluents whose production is increasing (e.g. the electronic industry).