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Review

Nitrogen management in landfill leachate: Application of SHARON, ANAMMOX and combined SHARON–ANAMMOX process

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ABSTRACT

In today's context of waste management, landfilling of Municipal Solid Waste (MSW) is considered to be one of the standard practices worldwide. Leachate generated from municipal landfills has become a great threat to the surroundings as it contains high concentration of organics, ammonia and other toxic pollutants. Emphasis has to be placed on the removal of ammonia nitrogen in particular, derived from the nitrogen content of the MSW and it is a long term pollution problem in landfills which determines when the landfill can be considered stable. Several biological processes are available for the removal of ammonia but novel processes such as the Single Reactor System for High Activity Ammonia Removal over Nitrite (SHARON) and Anaerobic Ammonium Oxidation (ANAMMOX) process have great potential and several advantages over conventional processes. The combined SHARON–ANAMMOX process for municipal landfill leachate treatment is a new, innovative and significant approach that requires more research to identify and solve critical issues. This review addresses the operational parameters, microbiology, biochemistry and application of both the processes to remove ammonia from leachate.

Contents

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1. Introduction

Persistence of ammonia nitrogen in leachate still remains a challenge in waste management. This is because MSW contains 1–4% of Total Kjeldahl Nitrogen (TKN) (Gallert and Winter, 1997; Ham et al., 1993; Jokela et al., 2001; Karthikeyan and Joseph, 2006; Onay and Pohland, 1998) which is primarily composed of proteins. This nitrogen from MSW is removed through ammonification and solubilization and accumulates as ammonia in the leachate owing to its stable nature under anaerobic conditions (Burton and Watson-Craik, 1998; Onay and Pohland, 1998; Berge et al., 2005). Total ammonia in aqueous solution consists of two main forms, the ammonium ion (NH_4^+) and the un-ionized ammonia (Free Ammonia (FA) – NH_3). At a temperature of 25 °C and a pH of 7, un-ionized ammonia amounts only for 0.6% of the total ammonia nitrogen, but at a temperature of 30 °C and a pH of 9.5, its amount increases to 72% of total ammonia nitrogen. FA, rather than ammonium, is the active substrate (Hellinga et al., 1999; van Hulle et al., 2007) and it is the most important nitrogen compound in surface waters and other ecosystems, for it is the preferred nutrient form for autotrophic bacteria and also provides buffering capacity in anaerobic digestion systems (Paredes et al., 2007). In conventional landfills, ammonia accounts for approximately 0.1–1.0% (dry volume basis) of landfill gas exiting the landfill (Tchobanoglous et al., 1993). An ammonia concentration in the range of 50–200 mg/L is reported as beneficial for microbial activity in anaerobic reactors and for the anaerobic degradation processes in wastewater treatment plants. An ammonia nitrogen concentration between 200 and 1000 mg/L has some detrimental effects and higher the concentration i.e., 1500–3000 mg/L, has an inhibitory effect particularly at higher pH. An ammonia concentration above 5800 mg/L has shown to be toxic to some microorganisms (Berge et al., 2005). The concentration of ammonia in leachate vary with the age of the landfill in the range of 100–5500 mg/L and this is detailed elsewhere (Renou et al., 2008). Hence, an ammonia nitrogen concentrations in leachate has to be removed because of its toxicity, has a high oxygen demand, requires post closure landfill maintenance, inhibits anaerobic degradation of waste, affects human health and to meet the discharge standard limits (He et al., 2007; Zhang et al., 2008; US Department of Health and Human Services, 2004). In India, according to the Ministry of Environment and Forests (MoEF, 2000) the discharge standard limits for ammonia is 50 mg/L. This discharge limits is similar to other countries like Europe. There are several methods to remove the accumulated ammonia nitrogen in leachate which can fall under two broad categories, namely, the physico-chemical methods (air stripping, activated carbon adsorption, filtration, ion exchange, precipitation) and biological methods (aerobic and anaerobic treatment). Physicochemical treatment is costly due to the added costs of sludge treatment, pretreatment that may be required in some cases, fouling problems, heavy chemical dosage and causes secondary pollution. Hence, biological treatment is considered to be economical with lower running and operating cost and is preferred when the ammonia nitrogen concentration is in the range of 100–5000 mg/L (Mulder, 2003; Janus and Vander, 1997).

Biological treatment is favoured even for organic matter removal from leachate. The organic matter varies according to the age of landfill leachate. The organic matter present in landfill leachates are typically volatile fatty acids, humic and fulvic compounds (Tengrui et al., 2007). The volatile fatty acids represented the largest group of organic compounds and this fraction showed a rapid decrease with increasing age of landfill. Fulvic compounds with a relatively high carboxyl and aromatic hydroxyl group density showed the most stable group of organic compounds with increasing age of landfill. Removal of organic matter (as BOD_5 and COD) from landfill leachate can be achieved similar to the ammoniacal nitrogen removal methods. The treatment of landfill leachate which had high or low BOD/COD ratio can be treated by biological methods including aerobic and anaerobic processes which is shown to be very effective (Klimiuk and Kulikowska, 2004).

This review focuses on the novel SHARON–ANAMMOX process, which has several advantages over conventional treatment for leachate, is timely. It extends on reviews on leachate treatment that addresses the conventional treatment processes, characterization of different leachate influents and its in situ conditions.

2. Nitrogen transformations and biological methods for ammonia nitrogen removal from landfill leachate

The existing biological methods for treatment of landfill leachate are aerobic and anaerobic processes using different treatment technologies like Activated Sludge system, Sequencing Batch Reactor (SBR), Membrane Bioreactor (MBR), Trickling Filters, Rotating Biological Contactors (RBCs) and Landfill Bioreactors (Berge et al., 2005; Long et al., 2008; Onay and Pohland, 1998; Renou et al., 2008; Tengrui et al., 2007). The mechanisms involved in biological leachate treatment are given below.

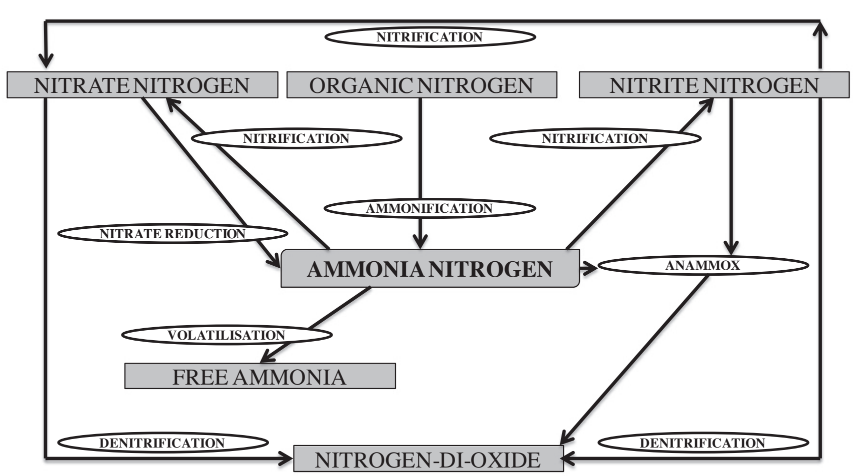

Fig. 1. Nitrogen transformations in landfill environment. Description: the figure illustrates the potential nitrogen transformation pathways/nitrogen cycle that may occur in bioreactor landfills. Processes commonly found in wastewater treatment processes and in soils, such as ammonification, sorption, volatilization, nitrification, denitrification, Anaerobic Ammonium Oxidation (ANAMMOX), and nitrate reduction, may all occur in landfills.