Ecohydrology & Hydrobiology 14 (2014) 132–141

Contents lists available at ScienceDirect

Ecohydrology & Hydrobiology

journal homepage: www.elsevier.com/locate/ecohyd

Review Article

# Nitrogen pollution removal from areas of intensive farming—comparison of various denitrification biotechnologies

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ARTICLE INFO

*Article history:*
Received 2 October 2013
Accepted 21 January 2014
Available online 8 February 2014

*Keywords:*
Denitrification barriers
Biotechnology
Nitrates Directive
Water Framework Directive
Nitrate removal
Groundwater

ABSTRACT

In recent decades, dynamic demographic processes resulting in an increased intensity of agricultural food production have changed the natural flow of nitrogen ($N_2$). This modification of the nitrogen cycle has led to number of changes. As nitrate is the most mobile form of nitrogen in soil, it is the most dangerous polluter of waters, and causes many diseases, including methaemoglobinaemia. Nitrogen contributes to the eutrophication of freshwater and marine ecosystems, resulting in the intensive development of toxic algal blooms and, often, the exclusion of affected freshwater from drinking water resources.

A literature review indicates that applying various biotechnologies to the denitrification process reduces the nitrogen load on the catchment scale by up to one order of magnitude, and seems to be an inexpensive tool for the reduction of nitrate loads to surface waters. Various reports underline the role of abiotic factors dependent on the climate, geology and management of agricultural areas. Depending on the specificity of a nitrogen pollution source, different biotechnological solutions can be applied in the field. For example, in a catchment with intensive farming or pasturing, around a point source such as manure storage, or near the coastline, denitrification walls can be an appropriate solution.

Protection and restoration should employ methods used for gradually developing the properties of the ecosystem responsible for its resilience and ability to respond flexibly to human pressure. These treatments are designed to restore the biogeochemical cycles of evolution-shaped properties and increase the resilience of the environment to human pressure.



## 1. Introduction

Nitrogen is an essential component of DNA, RNA and proteins in living organisms, and, in its molecular or ionic form, is a constituent of the lithosphere, hydrosphere, atmosphere, and biosphere. There are eight important processes in terrestrial nitrogen cycle: (1) uptake of nitrogen from the atmosphere (called symbiotic fixation), (2) uptake of ammonium ($NH_4$) and nitrate ($NO_3$) from the soil and water (called plant uptake), (3) ammonification, (4) nitrification, (5) denitrification, (6) nitrate immobilization, (7) nitrate leaching from the soil, and (8) release of

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http://dx.doi.org/10.1016/j.ecohyd.2014.01.005

ammonia ($NH_3$), gaseous nitrogen ($N_2$) and nitrous oxide ($N_2O$) to the atmosphere through volatilization from animal and poultry farms, and from manure, which is either applied to soil or stored (Pietrzak et al., 2002; Kurvits and Marta, 1998; Misselbrook et al., 2000; Sommer and Hutchings, 2001; Krupa, 2003; Sommer et al., 2003; Webb et al., 2005; Balsari et al., 2007; Desjardins et al., 2007; Erisman et al., 2007). These processes are schematically presented in Fig. 1. Microorganisms, particularly bacteria, play a key role in primary nitrogen metabolism and its cycle (Krupa, 2003; Sommer et al., 2003).

The production of food and energy for the growing human population since the mid-20th century was partially responsible for anthropogenic emissions of nitrogen compounds more than 10 times greater than those seen at the end of the nineteenth century. It is expected that the human population in 2050 will reach 9 billion, that is 30% more than today. Consequently, this will increase food demand, energy consumption and also nitrogen emissions from agriculture (Galloway et al., 2003), which in turn will result in more nitrogen spreading through the water and air. It is estimated that the amount of nitrogen retained in the soils of agricultural ecosystems ranges from 2% to 5%. The rest, about 50% is taken together with the crop, 25% is emitted to the atmosphere and a further 20–23% of the nitrogen flows into surface waters (Smil, 1999).

Nitrate ($NO_3$) is the most mobile form of nitrogen in soil and, hence, is considered to be one of the most dangerous pollutants of waters, contributing to the eutrophication of freshwater and marine ecosystems. Since the 1970s, nitrate contamination of groundwater has become a significant environmental problem in many parts of the world (Rivett et al., 2008; OECD, 2008). Webb et al. (2005) estimated that approximately 75% of European $NH_3$ emissions come from livestock production. According to the authors, these emissions occur at all stages of production: starting in the livestock buildings, through natural fertilizer storage and application to soil, up to the deposition of animal excreta on pastures. Fotyma et al. (2012) conclude that nearly 30% of N excreted by farm animals on the premises is lost during storage: about 19% being $NH_3$, 7% being nitrogen oxide (NO) and nitrous oxide ($N_2O$) emitted to the atmosphere, and approximately 4% being lost due to the leaching and outflow. Another 19% of the total N excreted by animals is emitted into the atmosphere in the form of $NH_3$ after the addition of manure to the soil. The spread of N losses from manure and slurry storage is significant for the 24 member states of the European Union (EU) as it was found to amount to 19.5–35% of the total livestock emissions. The most important activities leading to a significant reduction of ammonia emissions in livestock are: an adequate protein diet and regular cleaning of flooring, and the storage of manure in manure-finalized discs, leading a reduction of 70–90%; the application of natural fertilizers directly to soil, giving a reduction of 70–95%; and the use of biological filters to absorb ammonia (Geers and Kuczyński, 2005; Jongebreur et al., 2005; Huijsmans, 1998).

Leaching of nitrogen pollution from the area of intensive farming has largely been blamed for problems with methaemoglobinaemia and cancer risk in humans (Fan and Steinberg, 1996; WHO, 1999, 2004), other health and productivity disorders in livestock, and also environ-

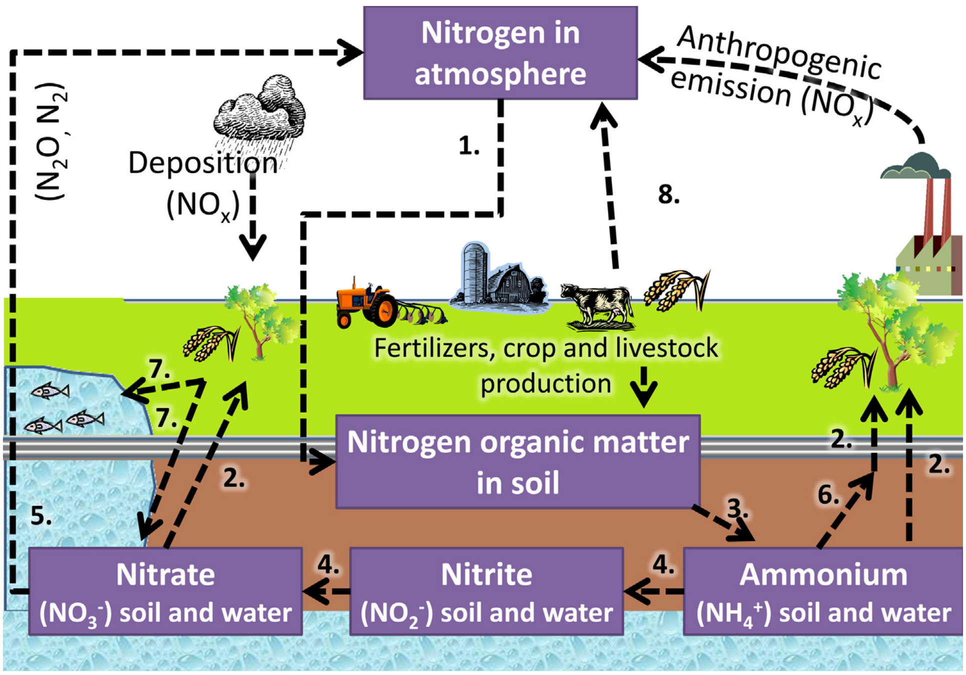


**Fig. 1.** The nitrogen cycle; (1) uptake of nitrogen by plants from the atmosphere, (2) uptake of ammonium and nitrate by plants from soil and water, (3) ammonification, (4) nitrification, (5) denitrification, (6) nitrate immobilization by soil sorption, (7) nitrate leaching from the soil, (8) release of ammonia (NH3), gaseous nitrogen and nitrous oxide to the atmosphere.