Biological Denitrification

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Denitrification is the biological reduction of nitrogen oxides rather than $O_2$ during anaerobic and microaerophilic respiratory metabolism. It is a microbial process, confined to prokaryotic organisms, although there have been reports since the 1970s that fungi denitrify (Bollag and Tung, 1972; Kobayashi et al., 1996; Shoun et al., 1992). However, based on biochemical characteristics, there does not appear at present to be sufficient justification to expand denitrifying potential beyond the bacterial world.

Denitrification is fundamentally important in the global biogeochemical N cycle because it is the major route by which inorganic oxidized N compounds in the soil return to the atmospheric N pool (Bowden, 1986). Denitrification causes fertilizer N losses from agricultural systems (Ryden and Lund, 1980) and produces nitric oxide (NO) and nitrous oxide ($N_2O$); two trace gases that contribute to global warming (Wang et al., 1976) and ozone reduction (Conrad, 1990; Crutzen and Ehalt, 1977). Denitrification is significant in removing nitrogen oxides from environments that may be adversely affected by available N (Smith et al., 1978), and denitrification blocks other respiratory processes such as sulfate reduction and methanogenesis by competing for available electron donors.

Several processes besides denitrification reduce nitrogen oxides: $NO_3^-$ respiration (Bleakley and Tiedje, 1982; Smith and Zimmerman, 1981), chemodenitrification (Stevenson and Cole, 1999), $NO_2^-$ dissimilation to $NH_4^+$ (DNRA) (Caskey and Tiedje, 1979; Kaspar and Tiedje, 1981), and $NO_2^-$ detoxification (Kaspar, 1982), but they are not denitrification; nor are processes such as nitrification that produce byproducts in common with denitrification (Blackmer et al., 1980; Hooper and Terry, 1979; Ritchie and Nicholas, 1972; Yoshida and Alexander, 1970). Pyrodenitrification, which generates $NO_3$ and $N_2$ during biomass (Kuhlbusch et al., 1991; Penner et al., 1991) and fossil fuel (Kasibhatla et al., 1993) burning, would also not be considered biological denitrification. These other processes will not be further discussed in this review.

The literature addressing denitrification is legion, consequently, this review will only briefly overview the background of denitrification studies and the cellular biology of denitrification; its main focus will be the environmental factors controlling denitrification in the soil environment, and the detection of denitrification in the soil microbial community. Except where relevant, denitrification in

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