Nitrogen Transport Processes in Soil

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Nitrogen is an essential plant nutrient, and the most abundant gas in our atmosphere. Human usage of N has expanded greatly in the last century, due to the exploitation of natural gas and oil reserves. Nitrogen fertilizer use has grown 20-fold in the USA over the last 50 yr, leading to significant increases in crop production (Keeney and Follett, 1991). The increased use of N as fertilizer has been linked to a variety of water pollution problems and changes in atmospheric chemistry (Tilman, 1999). The occurrence of groundwater with nitrate N concentrations exceeding 10 mg L$^{-1}$ is closely linked with overapplication of N from fertilizer and manure in agricultural regions with frequent irrigation or precipitation, shallow groundwater, permeable soils, and old or dug wells (Knox and Moody, 1991; Richards et al., 1996). The growth of the zone of hypoxia in the Gulf of Mexico (Rabalais et al., 1994) has been linked with heavy precipitation in the upper midwestern USA, along with excessive applications of N from fertilizer and manure on tile-drained soils used for row crop production (Turner and Rabalais, 1994; Goolsby and Battaglin, 2000; Randall and Mulla, 2001). Depletion of atmospheric ozone is partially explained by increasing amounts of nitrous oxide formed as a result of denitrification of nitrate in agricultural soils (Tindall et al., 1995). Keeping N in the soil is important for enhanced C sequestration from the atmosphere (Addiscott, 2000).

The net impact of N on the ecosystem depends on the relative importance of processes in the soil such as transport and storage (Haag and Kaupenjohann, 2001). Transport processes include leaching, preferential flow, seepage, interflow, runoff, erosion, and gaseous movement through denitrification and volatilization. Storage occurs through plant uptake, and immobilization or assimilation of fresh biomass into soil organic matter, while storage is diminished by mineralization. Mineralization can supply large amounts of nitrate for leaching, particularly during fall, when soils are remoistened by precipitation after crops have been harvested and soils have been tilled (Addiscott, 2000).

Nitrogen occurs in many chemical forms. The most common in the soil system are nitrate, ammonium, and various gaseous forms, including nitrous oxide and nitrogen gas. Nitrate is an anion, which is soluble in water. Ammonium is a cation, which is strongly sorbed to soil particles through cation exchange processes, and...