Organic Nitrogen Pool and Nitrate Leaching From Agricultural Soils: Isotopic Tracing ($\delta^{15}N\text{-}NO_3^-$ and $\delta^{18}O\text{-}NO_3^-$) and Modeling

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Analysis of the isotopic composition of nitrates released from agricultural soils of the central Parisian Basin, receiving mainly inorganic nitrogen fertilizers, and from other similar areas revealed that the $\delta^{18}O\text{-}NO_3^-$ values differed markedly from those of nitrate in fertilizers and atmospheric deposition. This indicates that leached nitrates are derived from nitrification of reduced nitrogen in the soil, instead of being directly transferred through the soil profile from applied fertilizers or atmospheric deposition. Also, the $\delta^{15}N$ values of nitrates were found to be different from those of nitrogen in inorganic fertilizers and atmospheric deposition, but similar to the □^{15}N values of organic soil nitrogen. We suggest that this difference is caused by the long term integrated effect of the processes of volatilization and denitrification affecting the nitrogen budget and the isotopic composition of nitrogen compounds in agricultural soils.

Increasing nitrate contamination of surface and groundwaters is a problem in many intensive agricultural areas of the world, particularly in temperate climate zones (Spalding and Exner 1993; Altman and Parizek 1995; Wassenaar 1995). Nitrate concentrations are increasing in rivers and in aquifers since the middle of the 20th century, closely paralleling the increase of the use of synthetic fertilizers as well as the increase of atmospheric nitrate deposition (Mariotti 1982; Meybeck 1990; Power and Shepers 1989; Donoso and others 1999). From these observations, it has often been implicitly assumed that nitrates applied to the soil with fertilizers and atmospheric deposition are directly leached through the soil profile. This view is supported by empirical relationships observed between nitrogen fertilizer application and nitrate leaching (Howarth and others 1996; Billen and Garnier 2000). However, bare soils, unfertilized fallow arable soils (Beaudoin and others 2005) and recently cleared forests soils (Likens and Bormann, 1975), are also subject to intense nitrogen leaching demonstrating that the mechanisms involved are much more complex and that the soil organic matter pool plays a significant role in nitrate leaching from agricultural soils.

The goal of this study was to summarize information on the isotopic composition of nitrate leached from agricultural areas that are dominated by N inputs via synthetic fertilizers and atmospheric deposition, and to compare the isotopic composition of the leached nitrate to that of the major nitrogen sources. The objective was to obtain novel information regarding the nitrogen sources and transformations that control the isotopic composition of nitrate and total organic nitrogen in agricultural soils.

Based on our own measurements of the natural isotopic composition of leached nitrates ($\delta^{15}N-NO_3^-$ and $\delta^{18}O-NO_3^-$) and organic matter in the agricultural soils ($\delta^{15}N$-Norg) of the central Paris basin (France) and on similar data gathered from the literature, we demonstrate that nitrate leaching from agricultural soils is usually the result of an intensive internal cycling of nitrogen with incorporation of applied or deposited inorganic nitrogen into the soil organic matter pool and subsequent mineralization. We also show that the nitrogen isotope ratio of the organic nitrogen pool of cultivated soils significantly differs from that of the primary sources of inorganic nitrogen from which it originates and suggest, on the basis of a simplified model of soil N turnover, that the difference in $\delta^{15}N$ values can be used as an integrated estimator of the importance of the processes of gaseous nitrogen loss due to volatilization and denitrification.

References

Altman SJ, Parizek RR. 1995. Dilution of non-point source nitrate in ground water. J. Environ. Qual. 24:707-18.
Beaudoin N, Saad J, Van Laethem C, Maucorps J, Machet JM, Mary B. 2005. Nitrate leaching in intensive arable agriculture in Northern France: effect of farming practices, soils and crop rotations. Agriculture Ecosystems and Environment 111:292-310.
Billen G, Garnier J. 2000. Nitrogen transfers through the Seine drainage network: a budget based on the application of the 'Riverstrahler' model. Hydrobiologia 410:139–50.
Donoso G, Cancino J, Magri A. 1999. Effects of agricultural activities on water pollution with nitrates and pesticides in the Central Valley of Chile. Water Science and Technology 39 (3): 49-60.
Likens GE, Borman FH. 1975. An experimental approach to New England Landscapes. In Coupling of Land and Water systems (ed A.D. Hasler). Springer Verlag Berlin pp 7-29.
Mariotti A. 1982. Apports de la géochimie isotopique à la connaissance du cycle de l'azote. PhD. Paris, France:Université Pierre et Marie Curie. 476 pp.
Meybeck M. 1990. La pollution des fleuves. La recherche 221:608-17.
Power JF, Schepers JS. 1989. Nitrate contamination of groundwater in North America. Agriculture, Ecosystems & Environment 26 (3-4):165-87.
Spalding RF, Exner ME. 1993. Occurrence of nitrate in groundwater- A review. J. Environ. Qual. 22:392-402.
Wassenaar LI. 1995. Evaluation of the origin and fate of nitrate in the Abbotsford aquifer using the isotopes of ^{15}N and ^{18}O in NO_3^-. Applied Geochemistry 10:391-405.