Oxygen isotopes in phosphate: Can it work in the soil/plant system?

Federica Tamburini[1], Stefano M. Bernasconi [2], Verena Pfahler[1], Emmanuel Frossard[1]

[1] Group of Plant Nutrition, D-AGRL, ETH Zürich, Switzerland; [2] Stable Isotope Laboratory, D-ERDW, ETH Zürich, Switzerland.

federica.tamburini@ipw.agrl.ethz.ch

First used as a paleotemperature tool (Longinelli and Nuti 1968), oxygen stable isotopes in phosphate (δ^{18}O-P) are gaining importance in understanding the phosphorus (P) cycling in the environment. The theoretical foundations for its use lie in the following points: in natural systems, P is bound to oxygen (O) which has three stable isotopes; inorganic processes at ambient temperature can not break P-O bonds, but organic processes can, promoting exchange or incorporation of O from ambient water; depending on the process at work, equilibrium or kinetic fractionation accompany these exchanges (Blake et al. 2005), but equilibrium seems to prevail in natural system. Enzymatic activities are suitable examples: inorganic pyrophosphatase, ubiquitous intracellular process, promotes temperature-dependent equilibrium between O associated to P and O in water. On the other hand, extracellular enzymatic catalysis of organic compounds, such as alkaline phosphatase, release inorganic phosphate, which partially inherits the signature of the original compound but also incorporates O with kinetic fractionation. Pioneering studies have focused on processes (Blake et al. 2005) and on the marine P cycle (Colman et al. 2005; Paytan et al. 2002). Only recently researchers have used δ^{18}O-P to track P sources in surface water bodies and soils (Elsbury et al. 2009; McLaughlin et al. 2006) and to understand soil development processes (Mizota et al. 1992). However, they were not fully successful in identifying processes and sources as little information on the effects of processes on the δ^{18}O-P of P pools and of P sources is available. But what can we really expect from using δ^{18}O-P in soils? Which processes will be paramount and to which extent the δ^{18}O-P of a soil P pool will be affected? We have developed a conceptual model where we consider inorganic and organic processes acting in the soil/plant system and fluxes between the different P pools accompanying these processes. Finally we hypothesize on the expected imprints on the δ^{18}O-P of the P pools. Results from preliminary experiments and field observations will support our model.

Blake, R.E., J.R. O'Neil and A.V. Surkov 2005. Biogeochemical cycling of phosphorus: insights from oxygen isotope effects of phosphoenzymes. Am. J. Sci. 305: 596-620.

Colman, A.S., R.E. Blake, D.M. Karl, M.L. Fogel and K.K. Turekian. 2005. Marine phosphate oxygen isotopes and organic matter remineralization in the oceans. PNAS 102(37): 13023-13028.

Elsbury, K.E., A. Paytan, N.E. Ostrom, C. Kendall, M.B. Young, K. McLaughlin, M.E. Rollog and S. Watson. 2009. Using oxygen isotopes of phosphate to trace phosphorus sources and cycling in Lake Erie. Environ. Sci. Technol. 43(9): 3108-3114.

Longinelli, A. and S. Nuti. 1968. Oxygen-isotope ratios in phosphate from fossil marine organisms. Science 160(3830): 879-882.

McLaughlin, K., B.J. Cade-Menun and A. Paytan. 2006. The oxygen isotopic composition of phosphate in Elkhorn Slough, California: A tracer for phosphate sources. Estuarine Coastal and Shelf Science 70: 499-506.

Mizota, C., Y. Domon and N. Yoshida. 1992. Oxygen isotope composition of natural phosphate from volcanic ash soils of the Great Rift Valley of Africa and east Java, Indonesia. Geoderma 53: 111-123.