Colloids Mediate Phosphate Leaching in Agricultural Soil: Observations and CD-MUSIC Modelling

RUBEN WARRINNIER[1*], THOMAS GOOSSENS[1], MIEKE VERBEECK[1], THIJS VANDEN NEST[2], FIEN AMERY[2], ERIK SMOLDERS[1]

[1]KU Leuven, Department of Earth and Environmental Sciences, Kasteelpark Arenberg 20 box 2459, 3001 Leuven, Belgium (*correspondence: ruben.warrinnier@kuleuven.be)

[2]Instituut voor Landbouw- en Visserijonderzoek (ILVO), Teelt en Omgeving, Burg. Van Gansberghelaan 109 bus 1, 9820 Merelbeke, Belgium (fien.amery@ilvo.vlaanderen.be; thijs.vandennest@ilvo.vlaanderen.be)

Phosphate (PO_4) leaching through the soil profile is a pathway by which waterbodies are enriched with phosphorus (P) in agricutural areas. Colloidal-mediated PO_4 leaching has been revealed before but it is unclear which factors contribute. Here, 123 columns, prepared from 40 different agricultural soils in Flanders (Belgium) and Feucherolles (France), were leached with artificial rainwater under unsaturated condition. Steady state P leachate concentrations ([P]) ranged from 0.001 to 0.235 mM P, out of which 113 exceeded 0.0045 mM P, i.e. the Flemish environmental limit for surface waters. The iron concentrations ([Fe]) in the leachates ranged from below detection limit to 1.4 mM. Moreover, aluminium concentrations ([Al]) in the filtrates correlated strongly with [Fe]. Both [Fe] and [Al] sharply increased with decreasing calcium concentrations ([Ca]), with largest concentrations below 1 mM Ca. The leachate [P] correlated remarkably strong with [Fe + Al] ($r = +0.68$ on log-log relationship) for soils with low P saturation (i.e. $P_{Ox} / 0.5(Fe_{Ox}+Al_{Ox}) < 0.30$, as measured in a soil oxalate extract). Multisite surface complexation modelling, with the CD-MUSIC model, predicted PO_4 leaching by including effects of organic matter anions and Ca on PO_4 sorption to particulate Fe- and Al(oxy)hydroxides *and* to colloids, with leachate Fe and Al as proxies for ferrihydrite colloids. The inclusion of the colloids improved predicted PO_4 leaching (RMSE of the $_{10}$log transformed [P] = 0.47). The fraction of predicted colloid-bound PO_4 increased with increasing [Fe + Al] ($p < 0.001$), yielding about a doubling of PO_4 mobility at 0.3 mM [Fe + Al]. Up to 96 % of PO_4, leached at steady state, was modelled to be colloid-bound. This study shows that high solution Ca, rather than high pH constraints colloidal PO_4 transport.