Identification of processes controlling phosphorus leaching from a long-term field experiment using the ICECREAM model

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Best management of animal manure and cultivation of catch crops are considered to be two important strategies to mitigate phosphorus (P) leaching losses from agricultural fields. However, no significant effect of either animal manure or catch crops on P leaching was observed in a long-term field experiment at Mellby in south-west Sweden. At this site, pig slurry has been applied at different rates, in combination with use of catch crops, since 1983. Measured P leaching results were evaluated for a 15-year-period (1989-2003) using the simulation model ICECREAM. The main objective was to explain the experimental data and to identify the critical processes controlling P leaching from this type of soil.

The experimental site consists of a layer of sandy soil overlying a glacifluvial clay at 90 cm depth, with an iron-rich subsoil (30-90 cm). Measured mean annual total P (TP) leaching was 0.17 kg ha^{-1} and mean annual concentration was 0.06 mg L^{-1}, of which 45% comprised dissolved reactive P (DRP). The ICECREAM model managed to accurately simulate the 15-year total drainage volume and drainage dynamics, as well as P leaching dynamics. Both simulations and measurements indicated a rapid flow of water through this soil, which constitutes a risk of fast transport of P to drainage pipes. However, the model overestimated TP and DRP concentrations in drainage water by a factor of approximately 10 and 18, respectively.

According to measurements, the long-term application of pig slurry has built up a high P content in the topsoil (P-AL: 38 mg P 100 g $soil^{-1}$) with a degree of P saturation (DPS) higher than 20%. The high soil P and DPS values indicate a high potential for P leaching. However, this was not reflected in the leaching measurements, probably because soluble P leached from the topsoil is adsorbed by Fe-oxides and/or Al-oxides in the far less P-saturated subsoil (DPS<20%). The sorption processes in the subsoil seemed to substantially reduce P leaching and counteract the effects of slurry application and cultivation of catch crops. The ICECREAM model did not account for the sorption capacity of Fe- and Al-oxides, which could explain the overestimation of DRP, and thus of TP concentrations, in the simulations. The sorption capacity of the subsoil is obviously substantial, providing good protection against leaching of dissolved P. According to the simulations, more than 70% of the manure P applied was retained in the soil, which could consequently be a potential source of future P losses. For example, with changes in hydrological conditions leading to wetter soil and more frequent reducing conditions, the risk of high P leaching losses would increase.

Although the Mellby soil has several properties (high soil P content, high DPS in the topsoil, high hydraulic conductivity) that could promote P leaching, the high sorption capacity in the subsoil seemed to negate the influence of these properties. To further improve the ICECREAM model, it is obviously necessary to account for the influence of Fe- and Al-oxides on P solubility.