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Optimizing Ammonia Volatilization Simulation in Agricultural Soils: Advancements of the EPIC Model

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Agriculture is responsible for about 94% of UE ammonia (NH_3) emissions, notably from livestock, manure management and soil fertilization. NH_3 volatilization is a significant cause of reactive nitrogen (N) loss, leading to lower fertilizer efficiency as well as environmental and health concerns. Loss predictions can be estimated using process-based biogeochemical models, but many of them lack precise estimations of NH_3 volatilization. In this work, we modified the Environmental Policy Integrated Climate (EPIC) model incorporating a mechanistic sub-model to simulate NH_3 volatilization following the application of N fertilizers in agricultural fields. The newly added algorithm in EPIC functions on an hourly time step and describes the ammonium (NH_4^+) adsorption by clay and organic matter and estimates the partitioning of total ammoniacal N into NH_3 and NH_4^+ based on the pH of the soil solution. The sub-model then determines the NH_3 concentration in the gas phase using Henry's law and estimates NH_3 emission using a mass transfer coefficient that considers the resistance in the turbulent and laminar layers. Additionally, the sub-model uses the soil's pH buffering capacity to recalculate pH following hydrogen ion consumption by urea hydrolysis and hydrogen ion release by NH_3 volatilization. The sub-model further integrates a reduction factor for volatilization to account for the effects of soil layer depth and the depth of fertilizer application. The new EPIC sub-model was validated using datasets from Veneto, NE Italy, and Georgia, USA. In Italy, NH_3 volatilization was measured in four experiments, testing cattle slurry, farmyard manure, and mixed silage maize and animal slurry digestate. Whereas in Georgia, NH_3 volatilization was examined following surface application of urea and poultry manure to grasslands. The new sub-model improved NH_3 loss prediction, yielding reasonable hourly NH_3 fluxes and cumulative volatilization estimates. As a result, the EPIC model exhibited lower prediction errors for soil mineral N (e.g. $NH_4^+$and NO_3^-) dynamics. While the new sub-model marks a notable advancement in accurately modeling N cycling, additional enhancements should prioritize certain modeling aspects, including slurry infiltration rates, NH_3 fluxes within the soil profile, and the mitigation effects resulting from urease inhibitor application.