Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.5724

Tracing the fate of phosphorus fertilizer derived cadmium in soil-fertilizer-wheat systems using enriched stable isotope labeling

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The application of mineral phosphorus (P) fertilizers represents a considerable input of the toxic heavy metal cadmium (Cd) into arable soils. Here, we investigated the fate of P fertilizer derived Cd (Cd_{dff}) in soil-wheat systems using a novel combination of enriched stable Cd isotope mass balances, sequential extractions and Bayesian isotope mixing models. We applied an enriched ^{111}Cd labeled mineral P fertilizer to arable soils from two long-term field trials with distinct soil properties (acidic and neutral soil pH) on which we cultivated wheat in a pot trial. In the past decades, these soils have received distinct mineral P fertilizer application rates that were below or above the Swiss fertilization guidelines.

Soil and wheat Cd concentrations increased with increasing past mineral P fertilizer rates in the neutral but not in the acidic soil. In the acidic soil, secondary effects such as enhanced Cd outputs through increased wheat biomass may have outbalanced Cd soil inputs. Less than 2.3% of freshly applied Cd_{dff} was taken up by the whole wheat plant while less than 0.3 % of Cd_{dff} was transported into the grains. Most of the freshly applied Cd_{dff} remained in the soil and >95% of Cd_{dff} was partitioned into the easily mobilizable acetic acid soluble fraction (F1) and the potentially mobilizable reducible fraction (F2). Soil pH was the determining factor for the partitioning of Cd_{dff} into F1 as highlighted by a recovery of about 40% of freshly applied Cd_{dff} in F1 in the neutral pH soil compared to about 60% in the strongly acidic soil. Isotope mixing models showed that F1 was the predominant Cd source for wheat on both soils and contributed over 80% of Cd that was taken up by wheat. By tracing the fate of Cd_{dff} in entire soil-plant systems using different isotope source tracing approaches, we showed that the majority of Cd_{dff} remains mobile and will be potentially plant available in the subsequent crop cycle. At the conference, these results will be used to discuss possibilities and limits of enriched stable isotope tracers to improve risk assessment of Cd and potential other trace metals in agriculture.