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Fate of cadmium in soils subject to application of biogas digestate and biofuel ash – mass balance modelling

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Nutrient-rich byproducts from the bioenergy sector can, in principle, replace a certain amount of mineral fertilizers, thereby contributing to reduced climate impact and to a circular economy. However, such byproducts may be relatively high in Cd, which could lead to unwanted soil accumulation and an increased Cd uptake to crops. Here we report results from a field experiment at Rådde, southern Sweden, where biogas digestate and biofuel ash were added to a sandy agricultural soil for a period of three years, and where Cd in crop offtake was measured. By use of data for the site, including soil extraction data for the A horizon, a mass-balance model was set up in which the Stockholm Humic Model (SHM) was used for predictions of future soil storage (through organic-matter complexation) and leaching. For this, the SHM had to be recalibrated for use at very low Cd/organic matter ratios, using a previously unpublished data set. With the application rates used, the ash and digestate amendments contributed to 1.55 g Cd ha^{-1} yr^{-1} combined, which can be compared to the 0.17 g Cd ha^{-1} yr^{-1} from conventional NPK fertilizer. The model results demonstrated that over time, this will lead to net accumulation of Cd in the soil, and therefore to increased crop uptake, as compared to the experimental start year in 2018. Moreover, the model clearly showed that the site is still far from steady-state with respect to current inputs of Cd from atmospheric deposition and fertilization, as these inputs have decreased more than tenfold since the 1970s. As a consequence, the reference state, against which assessments of accumulation are made, is continuously changing. The implications of the results obtained, with respect to risk assessment and current environmental goals, is discussed.