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REGIONAL MODELING OF CADMIUM LEACHING TO GROUNDWATER IN THE KEMPEN REGION, THE NETHERLANDS

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Sandy soils in the border area of Belgium and the Netherlands (the Kempen region), are heavily contaminated with cadmium and zinc by atmospheric deposition from nearby smelters. Leaching of heavy metals from the topsoil is a major risk for groundwater contamination. The sandy soils in the Kempen area are vulnerable for leaching due to the acidifying conditions in these soils. Regional modeling of groundwater contamination by leaching of cadmium from soils in a diffusely polluted area is the subject of this study. An attempt has been made to model the present and predict the future concentrations of cadmium in shallow groundwater and the metal binding processes in the unsaturated zone in the total Kempen area.

Leaching of cadmium is spatially highly variable. It depends on the soil type, the groundwater depth and cadmium input concentrations. In the Kempen area, the heavy metal load to the soil is controlled mostly by atmospheric deposition and the net rainwater infiltration. The atmospheric deposition of cadmium decreases strongly with the distance from the zinc smelters. In the mid-seventies, a change in production processes caused a sharp decline of cadmium emission. There is no temporal or spatial data available about the (historic) atmospheric deposition of cadmium covering the total Kempen region. Therefore, the atmospheric deposition of cadmium was reconstructed from the analyzed cadmium content in forest soil samples. Forest soil samples were chosen because the cadmium contents in these soils are not influenced by the use of manure, (lime) fertilizers and sewage sludge. For 13 locations with varying distances from the smelters the historic atmospheric deposition of cadmium was calculated by iteration with the analyzed cadmium content in the soil. Cadmium adsorption coeffi-

cients (K_F) for the individual locations, which are needed for these calculations, were derived with existing meta-models as a function of soil properties like pH, organic matter and clay content. In this reconstruction, the historic changes in deposition rates of cadmium were linearly related to the zinc production of the smelters. The calculated depositions at the 13 locations were spatially interpolated to an area-covering map of atmospheric deposition rates with the distance from the smelters and the predominant wind direction as input variables.

Leaching of cadmium from topsoil to groundwater is a function of soil type. Acid sandy soils of relatively low organic matter content demonstrate a low retardation capacity. The pH, organic matter, and clay content taken from the chemical characterization of soil types from the Dutch soil map were used to calculate Freundlich adsorption isotherms (K_F) for cadmium by using existing multiple linear regression models. Together with the groundwater level, this determines the breakthrough time of cadmium to the groundwater. Groundwater levels were derived from a regional groundwater model.

The unsaturated zone model HYDRUS was used to model the breakthrough of cadmium for all unique combinations of soil type, groundwater level and cadmium input load. The individual maps were classified to get a unique combination of input parameters. The Van Genuchten parameters for modelling the unsaturated water flow were calculted with pedo-transfer functions soil parameters like texture, bulk-density and organic matter content. The results of the regional modeling shows that groundwater recharge exceeds the Dutch groundwater intervention limits in 43% of the modeled Kempen area in 2002. In 2050 this will be 64%.