Uptake of soil cadmium by three field crops and its prediction by a pH-dependent Freundlich sorption model

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Abstract

Crop contamination with cadmium is a function of soil contamination. Here we study the applicability of the soil solution bioavailability hypothesis to Cd: that is, whether uptake of Cd was more directly related to its concentration or activity in the soil solution than in the soil solid phase. Experimental data from past soil-crop surveys for Cd were used to test this hypothesis. It was also investigated whether pH-dependent desorption of cadmium would be an important mechanism in affecting cadmium activity and thus uptake. To do so we calculated the correlation between the Cd transfer factor (ratio between Cd level in plant dry material and Cd level in the topsoil) and either the soil pH, or the calculated soil solution Cd concentrations.

There was no correlation between the Cd contents of the soil and of the edible parts of leafy plants (endive, spinach and lettuce). There was a strong negative correlation between soil pH and the log transfer factor for Cd at pH 4.5–7.2 and thus plant content. There also was a negative correlation between soil pH and calculated cadmium concentrations in the soil solution. For spinach grown on soils with pH > 7.2 the transfer factor increased, which is tentatively ascribed to cadmium mobilization by dissolved organic matter.

The soil solution hypothesis should be further tested by pot and field trials. Special attention should be paid to the role of pH and dissolved organic matter.

Introduction

In general, Cd concentrations in Dutch agricultural soils and crops are below permissible levels. At low soil Cd concentration solubility of Cd is believed to be controlled by sorption reactions rather than by precipitation. The distribution can be described by a Freundlich sorption equation, assuming binding site heterogeneity (Del Castilho and Bril, 1993). We can expect that a low coefficient of sorption for Cd, e.g. induced by a low pH, implies a high accumulation by crop plants. Gerritse et al. (1983) and Smilde et al. (1992) showed that Cd concentrations in soil solution extracts correlated well with Cd uptake by various crop plants.

The main purpose of the present study was to test the simple hypothesis that Cd concentration of the soil solution governs the cadmium levels in crops, with pH-dependent desorption of Cd being the main controlling mechanism. The hypothesis shares Sposito’s (1983) viewpoint: that the metal ion activity in the soil solution governs metal content in crops. Cd activity and concentration in the solution are both likely to show correlation with plant levels, because dissolved Cd species showed rapid dissociation kinetics (Del Castilho et al., 1993a), in contrast with e.g. Cu. Because soil solution data from previous surveys for Cd were lacking, they were calculated using a pH-dependent Freundlich sorption model. The soil pH as such, and its effect on Cd concentrations, were used for the prediction of Cd transfer.
Materials and methods

Crops

Agricultural soil surveys usually only present data (e.g. pH, heavy metal concentrations) for the topsoil layer, 0–30 cm. Crops like endive (Cichorium endivia L.), spinach (Spinacia oleracea L.) and lettuce (Lactuca sativa L.) form their roots almost exclusively in the topsoil. These crops are suited to test the soil solution hypothesis. Cadmium levels were measured using atomic absorption spectrometry (AAS) in rinsed plant material (normal domestic practice). Reference materials were used to monitor analytical quality.