AN EMPIRICAL MODEL TO PREDICT CADMIUM CONCENTRATIONS IN CULTIVATED SPINACH

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Introduction

To secure food safety, regulations for allowable concentrations of metals and metalloids in food crops are increasingly stringent. For cadmium (Cd), a maximum concentration of 0.2 mg/kg fresh mass is allowed in spinach (European Commission, 2015). These standards are strict, as they might be exceeded even when cultivating spinach on soils with Cd concentrations within normal baseline levels (Smolders, 2001). As the production sector is at real risk of being confronted with harvests where Cd concentrations exceed the maximum allowed concentration, selection of land and cultivation practices increasingly will need to account for the risk of Cd uptake. Hence, there is a need to estimate the risk to exceed maximum allowed concentrations when growing a crop on a selected field. An empirical model was established that allows to estimate such risk for a specific region.

Methods

Samples of soil and spinach were taken from production fields in mainly West Flanders and the north of Hainaut during the years 2014 (298 observations) and 2015 (94 observations). Soil was sampled from 0-30 cm, air dried and ground to pass a 2 mm sieve. Spinach plants were cut about 6 cm above the ground. Dry matter contents of the spinach plant were determined by drying until constant weight. Soil organic matter was estimated by loss on ignition at 550°C. Cation exchange capacity (CEC) was determined using the ammonium exchange method. Pseudo-total Cd content was determined using ICP-OES after aqua regia extraction. Cadmium was determined using ICP-OES after wet destruction of the fresh vegetable using nitric acid.

Linear regression models were explored to predict Cd contents in spinach (fresh mass based) from soil Cd content (dry mass based), soil properties, plant dry matter and growing period (spring, autumn or winter). A simplified regression model, that explained 75% of the variance, was selected for incorporation into an uncertainty model for practical application. A modeling approach based on Monte-Carlo analysis was used to estimate the risk of exceeding a threshold Cd concentrations. This involves recalculating the regression model many times, each time sampling the different input variables from a population characterized by a distribution that describes their variability. This results in a dataset of estimated concentration values. The percentage of the calculated values that exceeds the threshold is an estimate of the probability that Cd concentrations in spinach grown on that parcel might be exceeded.

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Results

Several variables were significant in explaining Cd concentrations in cultivated spinach. Up to 82% of the variability in Cd concentrations was explained by a more complex linear model that also included other elemental contents and interaction terms as significant predictor variables. A simplified model that involved soil pH, soil Cd concentration, soil texture class, plant dry matter and time of cultivation (spring, autumn or winter) as predictor variables still explained 75% of the variability. Because of the few input variables that are easily available, this linear model was considered as very suitable for use in a practical model that allows to estimate the risk of exceeding a critical Cd concentration in a crop grown on a specific field.

Figure 1 illustrates the output of a Monte Carlo simulation to calculate a distribution of possible Cd concentrations on a field with given properties. The fraction of calculated data that exceeds the threshold indicates the risk that Cd concentrations would be exceeded if spinach is grown on this field.

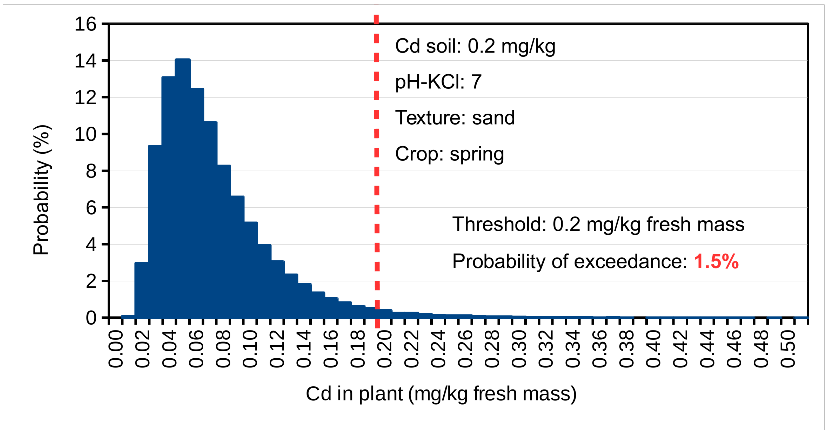

Figure 1. Output of a model calculation showing the histogram of possible Cd concentrations as assessed by Monte Carlo simulation

Baseline Cd concentrations on sandy soils in Flanders range from 0.1 to 0.3 mg/kg depending on the organic matter content in the soil (Tack *et al.*, 1997). The example (Figure 1) illustrates that for spring spinach, there is a chance of 1.5% to exceed the maximum allowed concentration on a soil with 0.2 mg/kg Cd and pH 7. This risk increases to 6.8 % if the pH would be 6. For winter spinach, the corresponding risks are 3.3% and 12.1%. This confirms that, in the context of the current legislation, Cd concentrations in the crop may be of concern even in uncontaminated agricultural soils. It is possible to quantify a region specific risk based on experience obtained through field data. This contributes to improving the control and management of metals in soils in relation to their potential transfer into the food chain.

References

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