Selecting Bioconcentration Factors for Minimizing Uncertainty in Probabilistic Exposure Assessment for Cadmium

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Introduction

In the non-smoking population without occupational exposure to cadmium (Cd), intake of this heavy metal mainly occurs via food (>95 %).

Vegetables and fruits (29-50 %) as well as cereals incl. baked goods (18-48 %) contribute most to the Cd intake via food (Fig. 1). Under present conditions in Central Europe, root uptake from soil is more important for the Cd status of crop plants than the direct uptake from

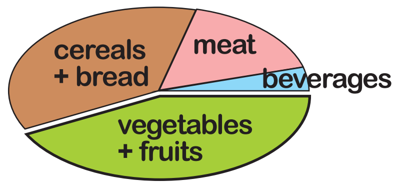


Fig. 1: Contribution of major food categories to Cd input by food. Mean values of aggregated data from different sources

Thus, **bioconcentration factors (BCF)**, describing the relationship between Cd content in (edible) plant organs and Cd in soil, are important input variables in exposure models representing Cd exposure of the general population.

The Issue

Bioconcentration factors (BCF) are sometimes derived from experimental data based on potted plants. Cadmium soil contamination is often mimicked by the additon of various Cd salts to the soil. These experimental conditions, however, differ from real-world situations, where Cd frequently occurs in forms bound to organic or inorganic constituents. Also, rooting behavior and metal uptake may deviate greatly between potted plants and field-grown crops.

Therefore, BCF values that are not based on field studies and are not using Cd forms of environmental relevance may be greatly biased. In addition, wehn applying Cd concentrations higher than may be expected under environmental conditions, BCF values are frequently underestimated due to the saturation characteristics of Cd accumulation in plants (Fig. 2A).

All these factors may contribute to unrealistic and highly variable values of BCFs, which are ill-suited as variables for exposure modeling. Therefore, a careful evaluation of the available literature was carried out to derive BCFs more relevant and realistic for probabilistic exposure assessment.

Methods

A total of 48 references on Cd uptake from soil to vegetable crops [pulses (bean, pea), fruit vegetables (tomato, bell peppers, cucumber, pumpkin), fruits and berries] has been evaluated to calculate BCF values.

Data were classified into 3 categories according to the environmental relevance of the experimental conditions:

1	greenhouse or growth chamber; potted plants	Cd as soluble salts
2	field, greenhouse or growth chamber; potted plants	Cd from sludge, dust, tailings, etc.
3	field-grown plants	Cd from sludge, dust, tailings; soils with high intrinsic Cd

If Cd content in relevant plant parts was non-linearly related to soil Cd content, only the lowest dosage was used to calculate the BCFs.

Summary

In probabilistic exposure assessment, bioconcentration factors (BCF) are crucial input variables for pollutants whose major path of exposure is through crops via root uptake from soil, as for cadmium.

When deriving BCF values, it is important to carefully select the underlying studies interms of environmental relevance. Some 48 publications have been critically evaluated and categorized according to the relevance of experimental set-up as well as the doses and chemical forms of cadmium applied.

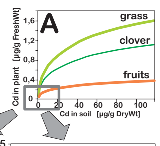
BCF values based on studies with high environmental relevance are remarkable less variable and closely follow log-normal distributions. Thus, uncertainty in probabilistic exposure assessment can be considerably reduced with BCF values are calculated and selected with care.

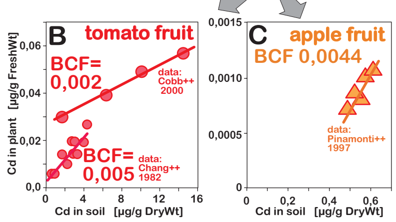
Results

Generally, soil conditions (pH, CEC, redox potential, organic substance, clay, Fe- and Al-oxides) govern the Cd availability in soil and thus the Cd accumulation in plants.

Within the same type of soil, however, significant relationships between soil Cd and plant Cd contents frequently occur. Cadmium accumulates more easily in roots and shoots than in fruits, and generally follows a saturation characteristics as soil Cd increases (Fig. 2A).

Fig. 2: Characteristic relationships between soil Cd and Cd in different crop organs (A; data from DUDKA et al., 1996). Examples for deriving BCF values for fruits from linear relationships between soil Cd and Cd in plant organs at low to moderate Cd levels (B+C)





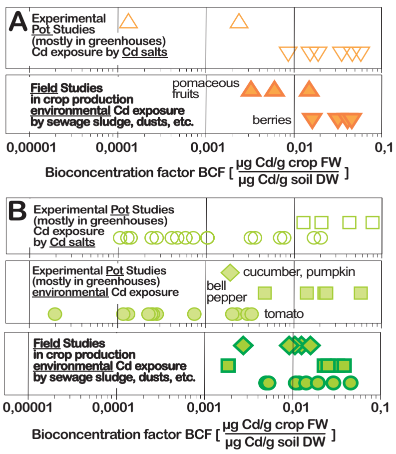


Fig. 3: Cd-Bioconcentration factors for pomaceous fruits and berries (A), and fruit vegetables (B) from various experimental studies, classified into 3 categories of environmental relevance.

Results (cont.)

At low to moderate soil Cd contents (<10 µg Cd/d DW) the relationship between plant Cd and soil Cd is close to linear and BCF values can be derived by linear regression (Fig. 2B+C).

When compared between the 3 categories of environmental relevance, the BCF values are generally more variable under experimental conditions of greenhouse pot studies, mostly using fairly high doses of Cd salts or other forms of Cd.

BCF values are far less variable when derived from studies under conditions of normal crop production (field studies) when applying Cd in environmentally relevant forms and doses. This holds true for tomatoes, bell peppers, pomaceous fruits and berries (Fig. 3A+B).

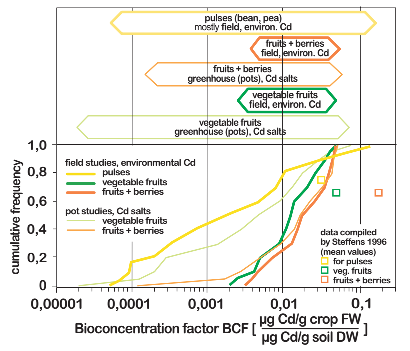


Fig. 4: Cd-Bioconcentration factors for pulses, fruit vegetables and pomaceous fruits and berries from various experimental studies: ranges of values and cumulative frequency plots

These BCF values normally do not span more than one order of magnitude, whereas BCF values derived from pot studies using soluble Cd salts (partially at high levels) may extend over 2 to 3 orders of magnitude (Fig. 4, top).

The BCF values from relevant studies are reasonably well characterized by log-normal distributions which is indicated by near-linear curves when BCF values are plotted on a log-scale versus cumulative frequency (Fig. 4, bottom).

Conclusion

Careful selection of data and their underlying experimental conditions is crucial to derive realistic BCF values. By this way, uncertainty in probabilistic risk assessment of pollutants for which uptake from soil is an important path of exposure may be considerably reduced.

References

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