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Radionuclide Soil-to-Plant Transfer - Experiences from the Chernobyl Accident in Austria

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SUMMARY

In field studies after the Chernobyl fallout in Austria distinct differences in soil-to-plant transfer of ^{137}Cs and ^{90} Sr between crops were observed. However, within single plant species transfer values varied over one to three orders of magnitude. The main influencing factors are the soil properties, the soil adhesion phenomenon and probably the unhomogeneous vertical distribution of the radionuclides after plowing. On the basis of the presented results we should be aware of the uncertainities of the simple soil-to-plant transfer model, which partly mask the influence of soil paramaters on root uptake and translocation.

KEY WORDS

^{137}Cs, Chernobyl, soil adhesion, soil-to-plant transfer, ^{90}Sr

DER BODEN-PFLANZE TRANSFER VON RADIONUKLIDEN, ERFAHRUNGEN NACH DEM REAKTORUNFALL VON CHERNOBYL IN ÖSTERREICH

ZUSAMMENFASSUNG

Feldversuche nach der Radionukliddeposition in Österreich ergaben deutliche Unterschiede des ^{137}Cs und ^{90}Sr-Boden-Pflanze Transfers zwischen den Feldfrüchten. Allerdings wurden darüber hinaus Schwankungsbreiten der Transferfaktoren von ein bis drei Größenordnungen innerhalb ein und derselben Pflanzenart beobachtet. Die wesentlichen Einflußfaktoren in diesem Zusammenhang sind die Bodeneigenschaften, das Phänomen der Bodenkontamination von Pflanzenoberflächen und wahrscheinlich die inhomogene Vertikalverteilung der Radionuklide nach dem ersten und zweiten Pflügen. Die Ergebnisse des einfachen Boden-Pflanze Transfermodells unterliegen somit mehreren Einflüssen, die die Wirkung der Bodeneigenschaften auf Wurzelaufnahme und Translokation teilweise maskieren.

SCHLÜSSELWORTE

Bodenadhesion, Boden-Pflanze Transfer, ^{137}Cs, Chernobyl, ^{90}Sr

RADIONUCLIDE SOIL-TO-PLANT TRANSFER, EXPERIENCES FROM THE CHERNOBYL ACCIDENT IN AUSTRIA

Introduction. The soil is the most important compartment of the ecosystem with respect to immobilisation or radionuclides. However, in long term the soil is a source for the uptake of radionuclides into plants und thus plays a major role in modeling the ingestion dose response to large scale contaminations. The radioactive fallout in Austria after the Chernobyl accident in 1986 made studies on the behaviour of ^{137}Cs and ^{90}Sr in the soil-plant system feasible.

Materials and Methods. In 1987 and 1988 soil and plant samples were taken at more than 100 sites in Lower Austria, Upper Austria, Burgenland and Styria. Transfer factors ([Bq/kg plant f.w.]/[Bq/kg soil d.w.]) for ^{137}Cs, ^{90}Sr and stable Sr were obtained and correlated to soil parameters.

Results and Discussion. Distinct differences in ^{137}Cs transfer values (TF) occurred between the investigated crops. Zucchini and cauliflower showed TF of only 0.0004. Cereal straw exhibited the highest values (Table 1). ^{137}Cs-TF into cereal grains were 2.3, 3.4, 4.9 and 5.0 times lower compared to straw for barley, rye, wheat and maize, respectively. Within single plant species TF varied over one to three orders of magnitude. Soil parameters like pH, clay and humus content showed minor correlations with TF. On the other hand, TF into straw of cereals were significantly correlated with ^{137}Cs-concentrations in the soil (Table 2). This effect can be explained by an influence of soil adhesion or an intercorrelation of soil parameters and contamination levels. Due to differences between wet and dry deposition areas, resuspension of ^{137}Cs-contaminated soil particles was higher in low contaminated regions as compared to high deposition areas (1). Thus, the contribution of the soil adhesion effect to plant contamination should be higher in low contaminated regions. Recent results of soil adhesion measurements (2) show that e.g. for barley and wheat straw ^{137}Cs derived from outer contamination can contribute in a range from 2.6 to 23.2 % to the total ^{137}Cs content (Table 3). However, this effect seems not to be sufficient to explain the phenomenon exclusively. Low transfer values were obtained in Upper Austria, where Eutric Cambisols are dominating. High transfer values were determined on the Chernozems of Lower Austria. Despite the fact that chemical and physical properties of these soils are quite similar, differences could be shown in a particle size fractionation experiment (3). ^{137}Cs in silt fraction was four times higher in the Calcic Chernozem than in the Eutric Cambisol (Figure 1). Extractability of radio-caesium from the organic matter of the silt fraction was considerably higher for the Calcic Chernozem as compared to the Eutric Cambisol (Figure 2). Further uncertainties in calculating plant contamination by the transfer model can be attributed to a lack of homogeneous ^{137}Cs vertical distribution in the soil after the first and second plowing (Figure 3), which may lead to under- or overpredictions using transfer factors based on a well defined contaminated soil layer (4).

^{90}Sr-TF for cereal grains were approximately 3 to 14 times higher than the respective values for ^{137}Cs obtained for the same samples (Table 1). Maize straw exhibited a 50 times higher TF compared to the grains, which is the ten fold discrimination compared to ^{137}Cs. This effect is due to the clearly lower translocation rate of strontium. In all cases soil-to-plant transfer of stable strontium was distinctly lower compared to the radioactive isotope. The TF for total stable strontium amounted on average only up to 60% of the respective values for ^{90}Sr. The respective linear regression was statistically significant (r = 0.908***). Thus, natural stable Sr was less plant available than ^{90}Sr from the Chernobyl and atomic bomb fallout. Statistical analysis showed a satisfactory correlation between exchangeable soil calcium and ^{90}Sr-TF. Due to ion competition Sr-uptake diminishes with increasing exchangeable Ca-contents of the soil. Soil adhesion obviously had no significant impact on Sr-TF.

Conclusion. We have to be aware of uncertainties of the simple soil-to-plant transfer model, which partly marks the influence of soil parameters on root uptake and translocation. Special attention should be given to radionuclide depth distribution in the soil during three years after fallout and the soil adhesion phenomenon in the case of radionuclides with low plant availability.

Literature Cited.

(1) Garland, J.A., Pattenden, N.J. 1989. Resuspension - rural and urban, including experience following Chernobyl. 2nd VAMP-Meeting, IAEA, Vienna, Dec. 5-8 1989.

(2) Li, J.G., Gerzabek, M.H., Mück, K. 1994. An experimental study on mass loading of soil particles on plant surfaces. Die Bodenkultur, in press.

(3) Gerzabek, M.H., Mohamad, S.A., Mück, K. 1992. Cs-137 in soil texture fractions and its impact on Cs-137 soil-to-plant transfer. Commun.Soil Sci. Plant Anal. 23:321-330.

4) Meisel, S., Gerzabek, M.H., Müller, Hj.K. 1991. Influence of plowing on the depth distribution of various radionuclides in the soil. Z. Pflanzenernähr. Bodenk. 154:211-215.

Table 1: Transfer factors for ^{137}Cs, ^{90}Sr and stable Sr for selected crops on a plant fresh weight - soil dry weight bases

		median		
crop		^{137}Cs	^{90}Sr	stable Sr
maize	straw	0.0116	0.494	0.208
	grain	0.0023	0.010	0.003
wheat	straw	0.0294	0.455	0.243
	grain	0.0060	0.049	0.026
rye	straw	0.0236	0.369	0.284
	grain	0.0069	0.097	0.027
barley	straw	0.0265	0.897	0.265
	grain	0.0116	0.095	0.038
potato	shoot	0.0100	0.625	0.359
	tuber	0.0024	0.029	0.015

Table 2: Correlation of ^{137}Cs soil-to-plant transfer factors with ^{137}Cs-concentration in soil

crop	equation	correlation coefficient
barley straw	$y = 0.325 \cdot x^{-0.696}$	-0.86
wheat straw	$y = 0.040 \cdot x^{-0.486}$	-0.85
maize straw	$y = 0.022 \cdot x^{-0.525}$	-0.79

y : transfer factor x : Bq ^{137}Cs/kg soil

Table 3: Soil adhesion on plant shoots from field studies after the Chernobyl fallout in Austria obtained by ^{46}Sc neutron activation method and its impact on radiocaesium plant contamination (Li et al. 1994).

Sample	mg soil/g dry plant [a]	Bq ^{137}Cs[b]/kg dry plant (% of total)
barley straw	6.01	0.141 (18.34)
barley straw	1.33	0.063 (05.53)
barley straw	2.31	0.087 (03.41)
barley straw	4.23	1.328 (23.18)
wheat straw	1.16	0.023 (02.61)
wheat straw	1.53	0.223 (14.48)

[a] Detection limit 0.05 mg soil/g dry plant;
[b] Radioactivity derived from soil adhesion.

Figure 3: Response of radionuclide vertical distribtion in a Stagno Dystric Gleysol to plowing after the Chernobyl fallout in Austria (MEISEL et al. 1991).

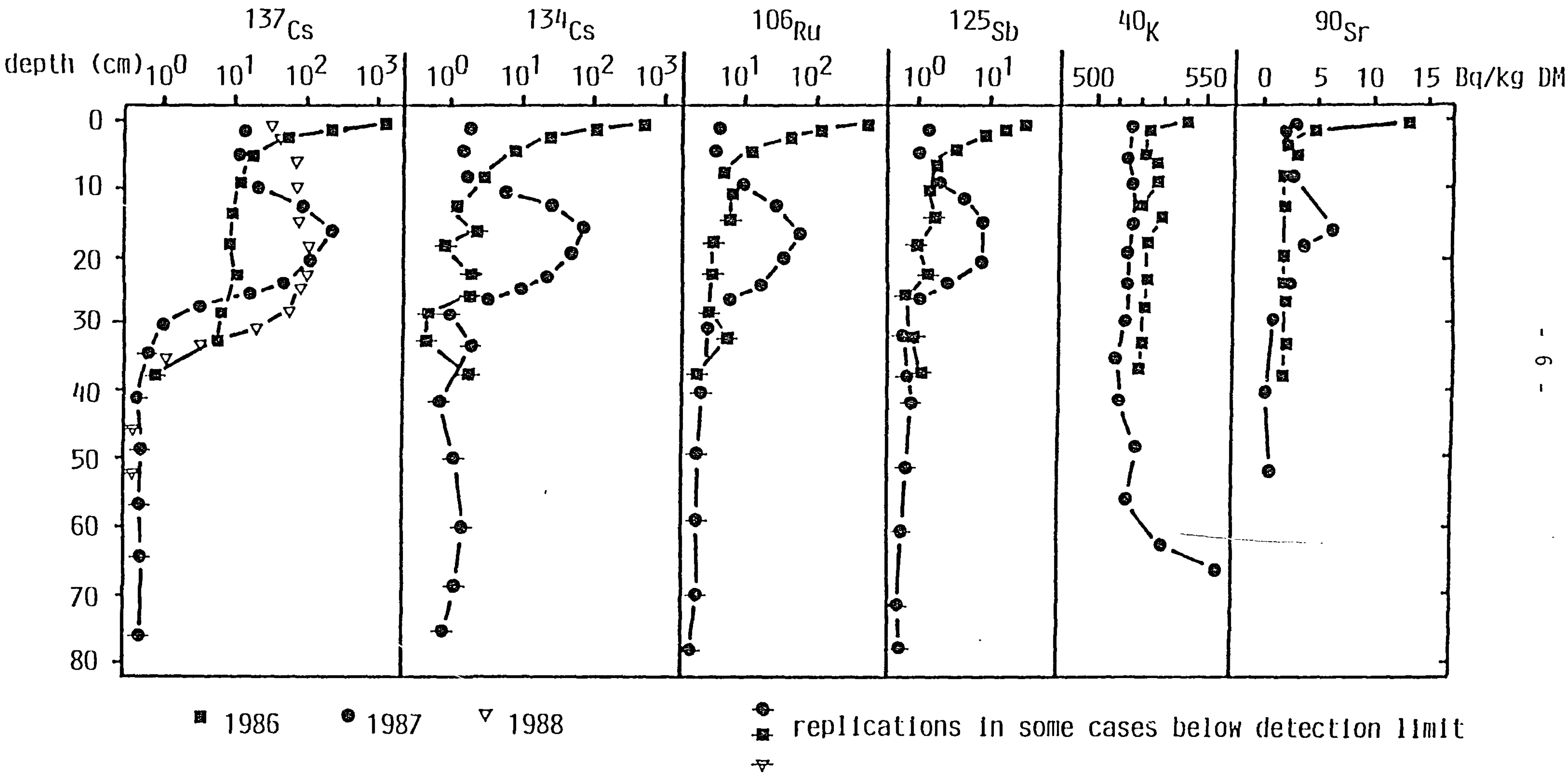


Figure 1: ^{137}Cs in the texture fractions of an Eutric Cambsiol (1) and a Calcic Chernozem (2) and median values of soil-to-plant transfer factors (TF).

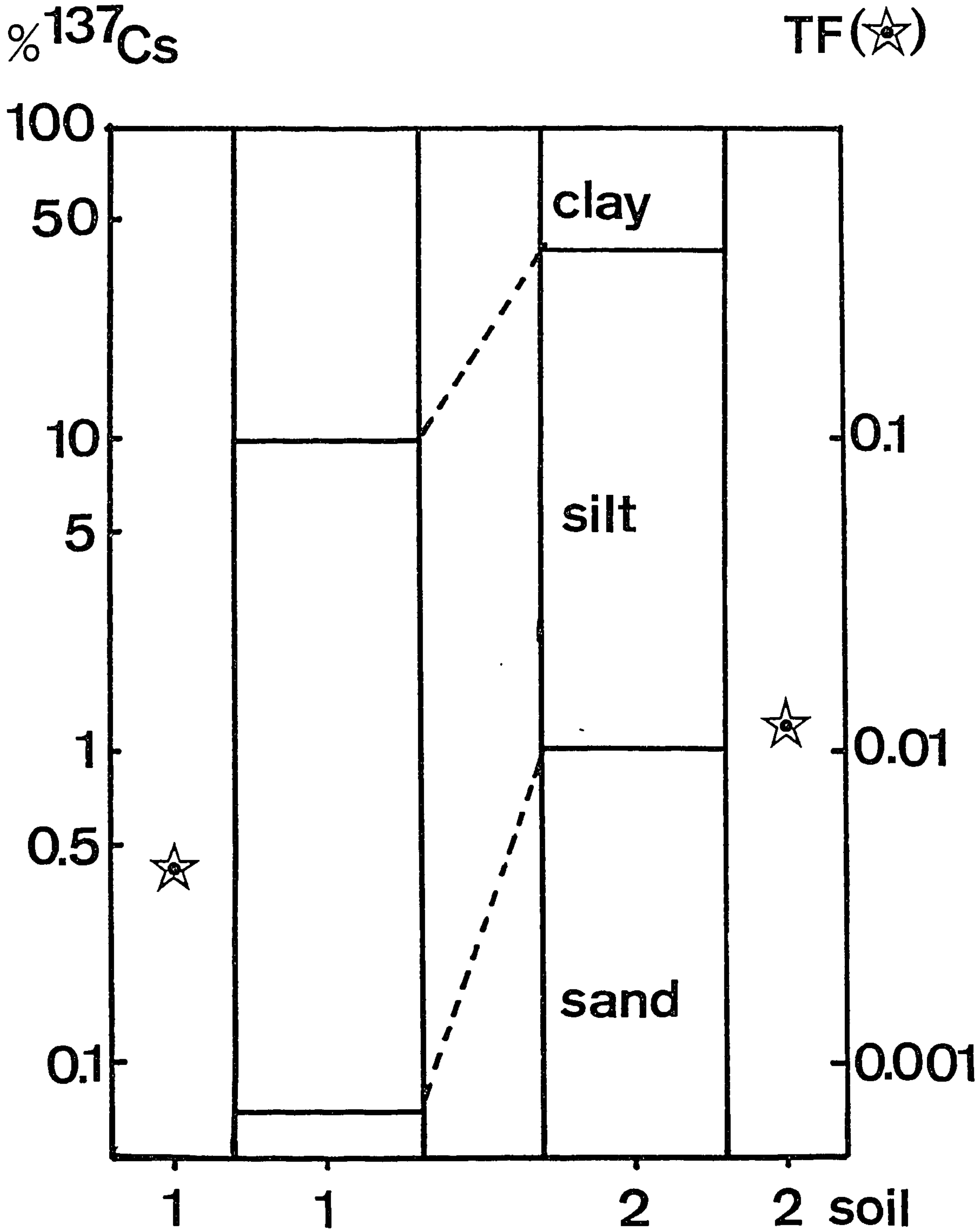
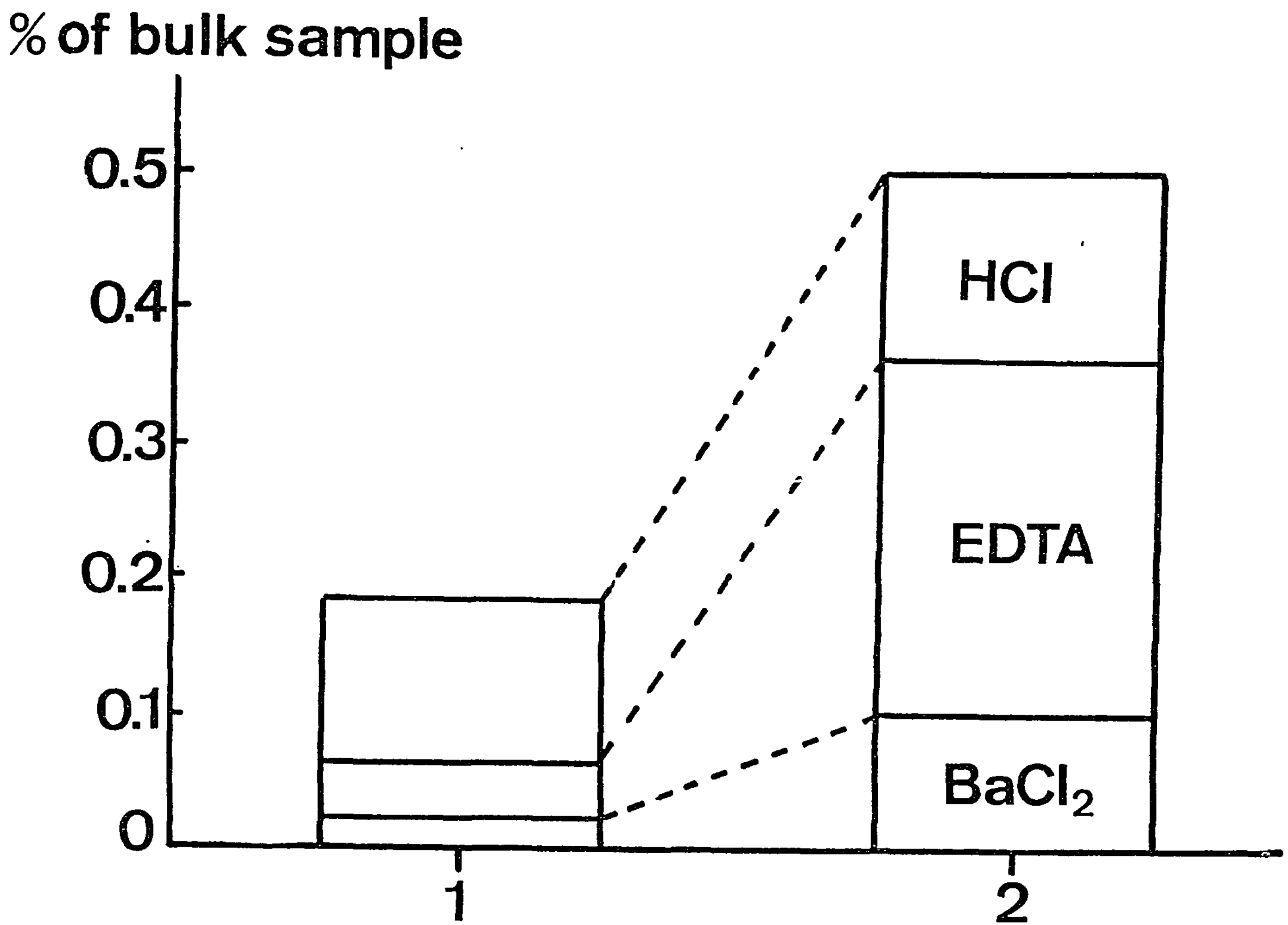


Figure 2: Extractable radiocaesium in the silt fraction of an Eutric Cambisol (1) and a Calcic Chernozem (2) in Austria.



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