Critical values of trace elements in soils from the viewpoint of the transfer pathway soil – plant

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ABSTRACT

The development of soil limiting values of the protection of the quantity and mainly quality of the crop production tends from empiric values towards critical values, based on ecotoxicity. We present an attempt to derive transfer functions by the means of multiple regression analysis. The substitution of trace elements contents in crops in the prediction equations for fodder or food standards or phytotoxicity limits satisfies the present ecotoxicological demands. We preferred polyfactor relations to simple ones. The exceeding of reference values must be verified by the determination of the hazardous transfer in the field. Therefore the reference values are called testing values. They were derived especially for Cd, Pb, As, Cu, Zn, Ni and Mn. For some trace elements, only protective values can be set up (especially for Cr, Hg, but also for Tl, Be, V). They reflect minimum values that guarantee growing crops without any risks. Experimental data (pot trials) were compared with results obtained in field investigations. The resulting critical values were also compared with the values proposed in Germany.

Keywords: trace elements; protection of crop quality and quantity; critical soil reference values

Since the beginning of all efforts to set up critical soil loading by trace elements (TEs) two standpoints were under consideration:

– consequences of the soil pollution by TEs on crop loadings, which cause the deterioration of the quality of food and fodder raw materials or the depression of the crop production,
– consequences of very high soil loadings in urban and industrial areas on the direct (oral, inhalative, dermatic) intake by humans.

More publicity, linked to the solution of humanotoxical (in the Netherlands also ecotoxicological) problems, was devoted to the second mentioned standpoint. We do not pay any attention to this problem in our paper.

The negative influences of TEs on agricultural soils were regarded at the beginning exclusively from the viewpoint of the hazardous contamination of soils by the waste disposal, mostly by sewage sludges. Criteria of the maximum permissible (tolerable) contents of TEs (later also POPs) in soils were elaborated in Germany (Kloke values, BGB 1987, 1992). At the beginning, they were undifferentiated but valid only at pH 6.5. Later they were differentiated in accordance with the pH and clay content. The range of critical values of soil contamination for sewage sludge disposal (EHC, Agra Europe 1986) was proposed for member states. In the USA, critical values were differentiated according to the CEC (cation exchange capacity) since the beginning. Later on, criteria valid for sewage sludges were often used like a general tolerable loading of agricultural soils.

In the Czech Republic (or former Czechoslovakia) the development of the mentioned criteria took place in a similar way. The regulation of the Ministry of Agriculture and Food was issued in 1987. This regulation comprised indicative and critical TEs values in soils. Later on new criteria of the maximum tolerable values were accepted within the regulation 13/1994 Sb. as a complement of the Agricultural Soil Protection Act (334/1992 Sb.). All the above mentioned criteria were expressed in TEs values extractable in the 2M HNO_3 and aqua regia. The original proposal was based on the investigations of crop uptakes and soil mobility responses of different soil units to the simulated loading by TEs. From six soil groupings only two were accepted in the regulation.

We can make a statement that all listed criteria of maximum tolerable TEs contents in soils are lacking any accurately defined methodological background of how they were derived. They are based only on pseudototal (or total, exceptionally 2M HNO_3 cold) contents.

Seventh types of orientative (bench-mark) values of limiting TEs contents in soils proposed by Eikmann and Kloke (1993) proves the fact that empirical criteria became universal for the evaluation of a healthy soil. Certain confusion within the problem of critical loading of agricultural soils was induced as a consequence of some efforts to use universally the Netherlands system (Leidraad 1982, 1988), in particular values A and B (two ranks of contamination). These values are in later versions increasingly ecotoxicologically supported, even the A values. However, this system has never been intended to be used for agricultural soils. In the Netherlands, another system is valid since 1991. Critical values of Cd, Zn, Pb, Cu, Ni, Cr, As and Hg serve to the protection of seven categories of crops. These values are differentiated for sandy, clayey, and organic soils. Peijneburg and Romkers (1999) delivered the information that an attempt is made to derive critical values from

TEs contents, pH, clay, and humus. Mobile species of TEs will be taken in account in transfer functions in the following steps (Tiktak et al. 2001).

Studies of TEs mobilities in soils in the linkage to the transfer pathway soil – crop represent the decisive contribution to the solution of the problem of a healthy soil. They must be based on characteristics of hazards and risk degrees caused by soil pollution.

The last mentioned crucial problem is being solved in three ways:

– toxicity tests, using some selected group of organisms; testing is carried out in soil extracts, very often from soils with a simulated pollution; criteria reflect the degree of the surviving of organisms,
– soil microbiological, zooedaphonological and biochemical tests; evaluation criteria involve responses in the presentation of organisms, in enzymatic processes, in the transformation of C and N etc. (Němeček et al. 1998, Podlešáková et al. 2000),
– investigation of TEs transfers into crops in relation to the achievement of critical loading of crops (Němeček and Podlešáková 2001, Podlešáková and Němeček 2001).

Even if we appreciate the significance of ecotoxicological, microbiological and biochemical tests, we regard transfer studies like the only one relevant. The relevancy of this approach rests upon the fact that the risk evaluation is in this case in harmony with a transfer pathway. The evaluation of the pollution hazards by biological tests is consistent with the transfer pathway only in case of the organic horizons of forest soils.

The investigation of the transfer of TEs into crops and the evaluation of the risk is linked to the solution of two problems:

– the dependence of the TEs transfer into plants upon the content of single elements in soils, their mobilities, conditions determining this mobility and on specific features of the transfer of single TEs into different crops,
– the ecological relevancy of crop loadings, which is more easily evaluated in case of phytotoxicity, but is difficult to assess in case of zootoxicity and humanotoxicity.

The first mentioned problem is discussed in our previous contributions (Němeček and Podlešáková 2001, Podlešáková and Němeček 2001, Podlešáková et al. 2001). The ecological relevancy of crop loading is being achieved by making use of fodder plant standards, exceptionally by values above the natural background of crops (e.g. beryllium).

We have more detailed information concerning the phytotoxicity. Magnicol and Beckett (1985) summarized in a comprehensive study results of investigations of many authors focused on phytotoxicity. The concentration of TEs in plant tissues when the production of dry matter decreases by 10% was taken for the critical level of toxicity. These values were estimated for 20 elements. The following ranges of critical values in crops were found (in $mg.kg^{-1}$ d.w.): Cd 8–25, Cr 2–8, Co 10–20, Cu 10–20, Mn 100–400, Hg 1–6, Ni 10–20, V 2–6, Zn 150–300. Critical phytotoxic concentrations of mobilizable species (0.05M EDTA) in soils were set up in $mg.kg^{-1}$: 25 Cu, 200 Zn, 50 Ni.

What concerns the threat to the food chain the situation is rather complicated. Vollmer (1995) asserts that standards of tolerable contents of TEs in food and fodder crops are not ecotoxicologically supported, but statistically fixed. That is the reason why critical values for the transfer pathway soil – crop included in the German Soil Protection Act and its regulations (BBod Sch G 1998, Regierungsentwurf 1999) are not considered as limiting values for the protection of food chain, but (Delschen and Rück 1997) are regarded as limiting values of the quality of products, that determine their market utilization. Safe use of fruits and vegetables from city gardens are also evaluated in this manner.

Soil scientists have no other possibility than to adjust critical soil loading, derived from transfer functions on fodder and food crop standards. This has been made in Germany (Bachmann 1997, Delschen and Rück 1997, Delschen 1998, Delschen and König 1998 and others) based on the evaluation of comprehensive transfer studies soil – crop (Knoche et al. 1997) by the LABO group (1998). The set of pairs soil-plant was processed by the regression analysis for the data concerning pseudototal (aqua regia) and mobile species of Cd, Tl, Zn, Ni, Cu, As in soils and the total contents in crops. Critical soil loadings were determined from the viewpoint of:

Table 1. Generic testing critical values of the mobile (1M NH_4NO_3 – MN), mobilizable (0.025M EDTA – ED) and total TEs content (TO)

Trace element	MN ($mg.kg^{-1}$)	TO ($mg.kg^{-1}$)	ED ($mg.kg^{-1}$)	ED/TO (%)	Critical plant concentration ($mg.kg^{-1}$ d.w.)
Cd	0.06 (> pH 5)	2.0 (> pH 6.5)	–	> 40	1.1
Pb	1.0	500	–	> 40	5
As	1.0	1500	–	< 5	2
	0.5	50	–	> 5	
Cu	1.0	100	50	> 50	10
Zn	30	500	> 100 (pH > 5)	–	150
Ni	4	100	–	–	5
Mn	100	2000	–	–	250
Co	2	100	–	–	6

– the phytotoxicity – As, Cu, Ni, Zn,
– the zootoxicity for fodder plants – As, Pb, Cd, Cu, Ni, Hg, Tl,
– crops used as food raw materials – As, Pb, Cd, Hg, Tl.

Prüeß (1992) fixed critical values based on 1M NH_4NO_3 extract not only for the quality of food, fodder plants and phytotoxicity, but also for another soil functions. There were derived also generally oriented values of mobile species for 19 elements. These criteria are included in the Soil Protection Act for Baden Württenberg (Bod Sch. G.B-W 1991, Umweltministerium).

Table 2. Protective critical values of the mobile species (MN) and the total TEs content

Trace elements	Mobile species MN ($mg.kg^{-1}$)	Total content TO ($mg.kg^{-1}$)	ED/TO × 100
Tl	0.05	10	–
Be	0.20	8	–
V	0.50	400	–
Cr^{III}	0.05	1500	< 1
		500	> 1*
Hg	–	1	–

* testing of CrVI recommended

MATERIAL AND METHODS

The methodology of pot experiments and field investigations was described in previous contributions (Němeček and Podlešáková 2001, Němeček et al. 2001, Podlešáková and Němeček 2001).

In soils and plants from pot experiments (54 soil samples) and field investigations (125 sites) with soils contaminated in the field conditions there have been determined:
– in soils: total content of TEs (TO), content of potentially mobilizable (ED – 0.025M Na_2EDTA), mobile (MN – 1M NH_4NO_3, MC – 0.01M $CaCl_2$) species; pH, soil texture and humus content and quality,
– in plants (radish, triticale) total content of TEs.

This paper focuses on the generalization of the conducted investigations to set up critical soil loadings of the following TEs: Cd, Tl, Pb, Zn, Ni, Mn, Co, Cu, As, V, Cr, Hg.

They were derived from prediction equations by substitution of crop TEs content by crop critical values (fodder standards). This processing reflects critical transfer rates. Critical soil characteristics, which affect critical transfer rates, were calculated in two ways:
– taking into account mean values,
– taking into account also variances.

Critical soil parameters (combination of characteristics) derived by means of transfer functions are called **testing reference values** (Prüfwerte in Germany). The exceeding of these values is followed by verifying the transfer soil – crop on the site.

Critical values derived only from one variable (e.g. MN, TO, clay, pH) can be misleading, because they express limits, which represent average conditions and do not take into considerations factor interactions. We prefer graphical presentation for more complicated relationships.

The **protective values** were proposed for TEs with a low mobility in soils, but also for TEs with higher mobility but low transfer quotients. They express minimum total contents or minimum mobile or potentially mobilizable species that guarantee the unhazardous behavior of the soil. Very helpful information provided also studies of extreme TEs values in soils.

Objections are expected to the setting up critical values in pot trials. This procedure is preferred to field investigations. Representative set of soil samples with a wide range of properties and types of contamination can be used and examined in comparable conditions. Field observations reflect lower transfers, measured in complicated conditions.

Another objection concerns transfer quotients of different crops. No proper accumulators however have been used, even when radish shows higher transfer quotients of mobile species of some TEs. Resulting criteria have been derived from the most severe data that have been acquired.

Both testing and protective reference values are confronted with German reference values destined for the same purpose. We use the following abbreviations:
– German Soil Protection Act 1998 – GSPA,
– Baden-Würtemberk Soil Protection Act 1993 – BWSPA.

RESULTS AND DISCUSSION

Generic soil testing values, which have been derived from simple relations (equations) are given in the Table 1. They have been compared with results obtained in soils with severe anthropogenic loading and geogenic high TEs contents and with results obtained from interactions of 2–3 factors on critical transfer soil – plant. They are expressed either in total TEs contents or in mobile or mobilizable TEs species contents with additional information concerning the mobility (ED/TO × 100), which reflects differences between TEs anthropogenic loads and geogenic contents. Protective values are presented in Table 2.

The above noticed soil critical values (Tables 1 and 2) for the protection of the quality and quantity of the crop

Table 3. Soil differentiated critical values of the mobile (MN) Cd species

Mobile species ($\mu g.kg^{-1}$)	Soils
50	sandy soils
80	prevailing soils
150	soils with a clay content > 25%
200	chernozems, phaeozems (loamy)

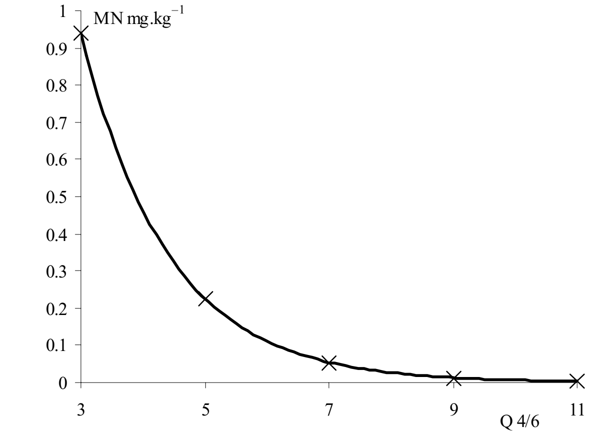


Figure 1. Dependence of critical transfer of Cd into upon the content of the mobile species (MN) and humus quality ($Q_{4/6}$) in soils

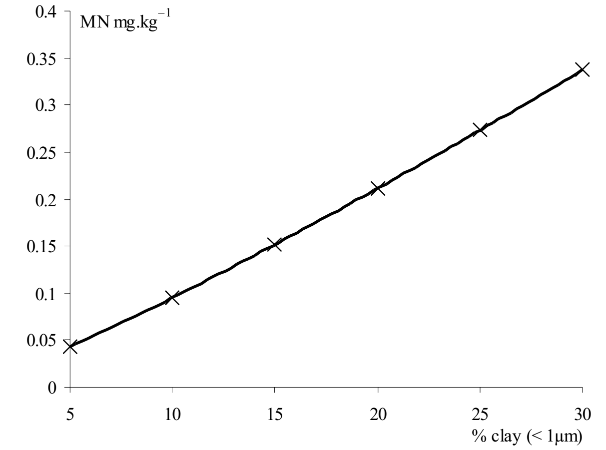


Figure 2. Dependence of the critical transfer values of Cd into radish upon the content of mobile species (MN) and clay (< 1 μm) content (C) in soils

production are regarded as the first piece of information. The next step rests upon the evaluation of two or three soil characteristics, which affect the critical transfer into crops. This interaction are described and displayed in figures one trace element after another.

Cadmium

Following testing reference values were derived:

– values based on the dependence of the critical transfer on the content of the mobile species of Cd and humus quality in soils (Figure 1) and on the content of the mobile species of Cd and clay content in soils (Figure 2); the simplified differentiated critical content of the mobile species (MN) of Cd are given in the Table 3,
– values based on critical transfer interactions between the total (TO) Cd content and the pH in soils (Figure 3): pH 3 – 0.6 mg.kg^{-1} (background value), pH 4 – 0.9 mg.kg^{-1}, pH 5 – 1.2 mg.kg^{-1}, pH 6 – 1.7 mg.kg^{-1}, pH 7 – 2.4 mg.kg^{-1},
– values based on interactions between the total (TO) Cd content and the content of the mobile species (MN) of Cd in soils (Figure 4): TO 0.5:MN 0.08 mg.kg^{-1}; 1.0:0.055 mg.kg^{-1}; 1.5:0.04 mg.kg^{-1}; 2.0:30 mg.kg^{-1} and 3.0:0.022 mg.kg^{-1}.

Subsets of soils lacking Fluvisols and another anthropogenically contaminated soils are characterized by critical values of the mobile species (MN), which are more severe than in the whole set. This is due to the fact that anthropogenically polluted soils are characterized by the increased solubility of the potentially mobilizable species (ED) accompanied by lower contents of mobile (MN) species.

The content of mobile species (MN) of Cd does not exceed 250 μg.kg^{-1} at pH 4.5 and 160 μg.kg^{-1} at pH 5 even if the total content of Cd reaches 3 mg.kg^{-1}.

Whereas Prüeß (1992) mentioned a testing value 20 μg.kg^{-1} and BWSPA 25 μg.kg^{-1} in 1M NH_4NO_3, the GSPA presented more realistic values: 100 μg.kg^{-1} and 40 μg.kg^{-1} as a very strict value for the food raw materials. The paradoxical high pseudototal content 20 mg.kg^{-1} Cd is proposed for grasslands. The critical value of the

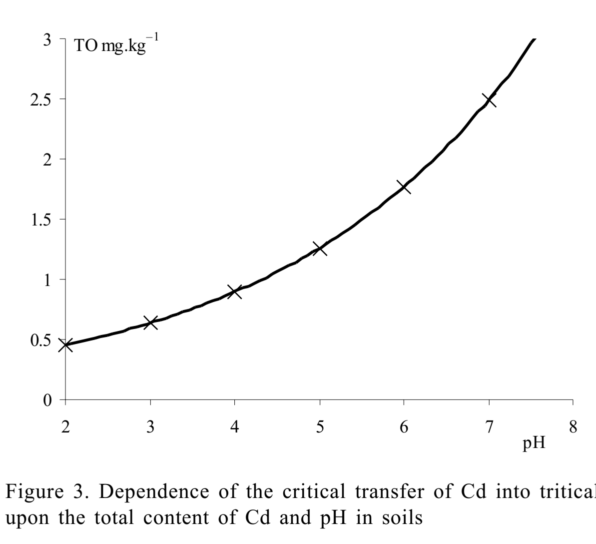


Figure 3. Dependence of the critical transfer of Cd into triticale upon the total content of Cd and pH in soils

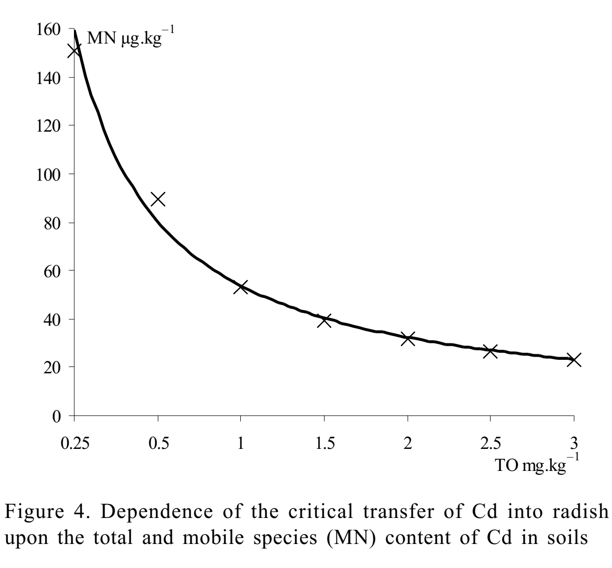


Figure 4. Dependence of the critical transfer of Cd into radish upon the total and mobile species (MN) content of Cd in soils

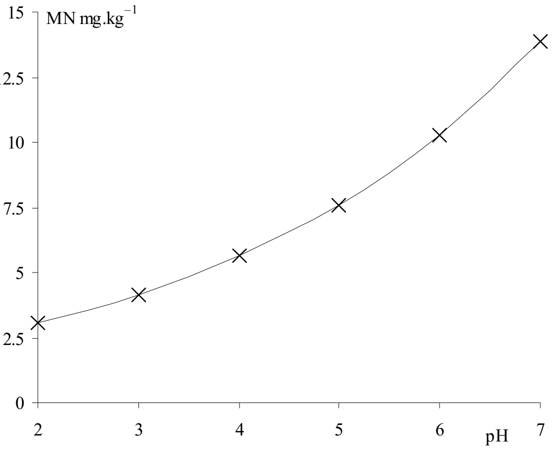


Figure 5. Dependence of the critical transfer of Pb into radish upon the mobile species (MN) content and pH in soils

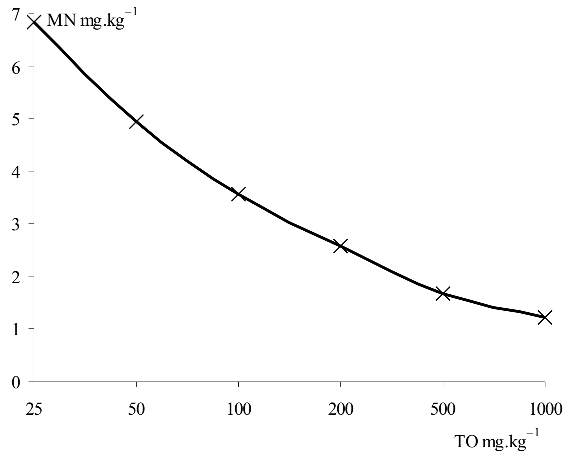


Figure 6. Dependence of the critical transfer of Pb into radish upon the mobile species (MN) and total content of Pb in soils

pseudototal content in the BWSPA is differentiated in the following way:

– 1 mg.kg^{-1} for coarse textured soils at pH 4–5 and for another soils having pH 5–6,
– 1.5 mg.kg^{-1} for topsoils with pH > 6.

Lead

More reliable then generic critical soil testing values can be assessed from the Figures 5 and 6. Figure 5 displays the dependence of the Pb transfer (into radish) on the mobile species (MN) content and the soil pH. Critical values of MN at different pH levels are as follows (pH–MN): pH 3 – 4 mg.kg^{-1}, pH 5 – 7.5 mg.kg^{-1}, pH 6 – 10 mg.kg^{-1}, pH 7 – 14 mg.kg^{-1}. Figure 6 shows how the total content (TO) and the mobile species (MN) content affect the transfer (into radish). Critical values of the mobile species (MN) are growing more severe from 5 mg.kg^{-1} MN at 50 mg.kg^{-1} Pb to 1.7 mg.kg^{-1} at 500 mg.kg^{-1}. The content of the mobile species of Pb (MN) in the investigated set surpasses the content 1 mg.kg^{-1} only at pH < 4 at the total Pb content > 500 mg.kg^{-1}.

Figure 7 reveals very interesting relations. The higher is the solubility (ED/TO × 100) at the same total Pb level, the less severe (= higher) is the corresponding critical content of the mobile species (MN). It is due to the fact, that the increase of the solubility (in average from 44% to 72%) in anthropogenically contaminated soils is accompanied by the sinking values of the relative content (MN/TO × 100) of the mobile species because of the slightly acid conditions, especially in Fluvisols.

Critical loads of mobile species within subsets lacking anthropogenically contaminated soil are more severe (analogy with Cd).

Both critical values of mobile species (MN) 100 and 500 µg.kg^{-1} set up by Prüeß and 400 µg.kg^{-1} in the BWSPA are too strict. The critical values of the pseudototal content 1200 mg.kg^{-1} in the GSPA are more realistic.

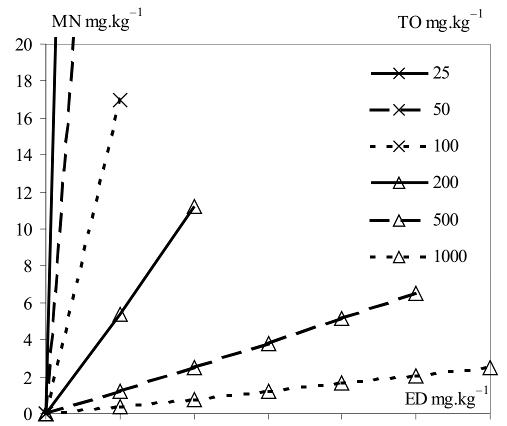


Figure 7. Dependence of the critical transfer of Pb into radish upon the mobile species (MN) and mobilizable species (ED) at different total content (TO) levels of Pb in soils

Arsenic

Figure 8 reflects the participation of both the mobile species (MN) and solubility (ED/TO × 100) of As at different levels of the total As content in the critical transfer soil – plant. Critical values of the mobile species (MN) become stricter along with the increasing solubility and the total content of As. Critical content of the mobile species (MN) more severe than 0.5 mg.kg^{-1} can be reached at As concentrations more than the total As content 100 mg.kg^{-1} at higher solubility than 30%.

GSPA points to the critical As values 200 mg.kg^{-1} in aqua regia for cropland and 50 mg.kg^{-1} for grassland soils and 400 µg.kg^{-1} of the mobile species (MN) for phytotoxicity. Prüeß (1992) presents 100 µg.kg^{-1} of the mobile species (MN) for the protection of crop production quality and 600 µg.kg^{-1} for phytotoxicity. BWSPA involves critical values of the mobile species (MN) 140 µg.kg^{-1} for the

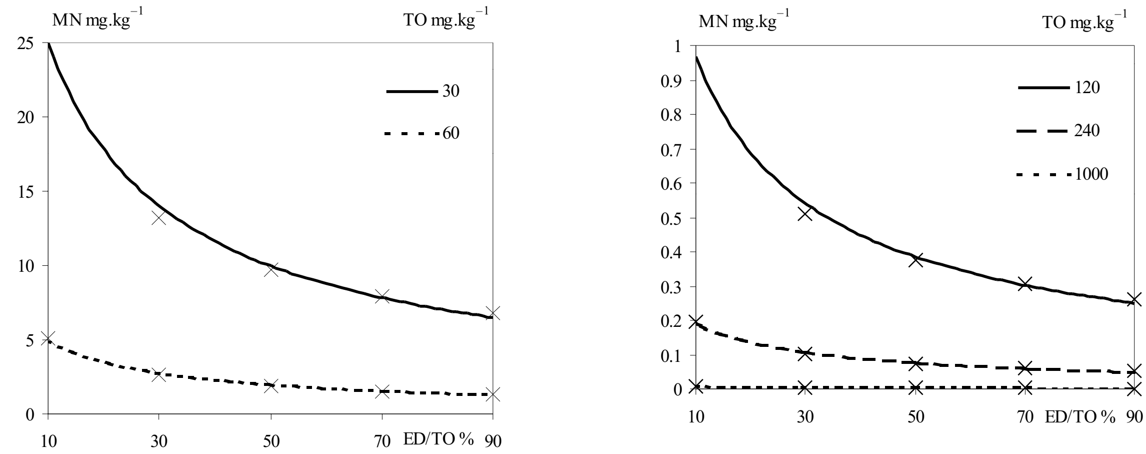


Figure 8. Dependence of critical transport of As into triticale upon the mobile species (MN) content of As at different levels of total content (TO) of As in soils

quality protection and 800 μg.kg^{-1} for phytotoxicity and the pseudototal content 20 mg.kg^{-1} (for the coarse textured) or 40 mg.kg^{-1} (for the other soils).

Copper

The following critical values were derived:

– values derived from interactions between the content of the mobile species (MN) and pH (Figure 9), critical values of Cu mobile species show that the generic critical value 1.0 mg.kg^{-1} at pH > 6.5 decreases to 0.2 mg.kg^{-1} at pH 5 and on less then 0.1 mg.kg^{-1} at pH 4; critical values become more severe at low pH,

– the more sophisticated approach reflects (Figure 10) how the critical transfer of the mobile species (MN) is the most severe at low pH and high total content (TO) of Cu values.

The critical content of the mobile species (MN) increases with increasing solubility (ED/TO × 100) but with the sinking of the total Cu content (probably due to the complexity).

In the GSPA the content of Cu 200 mg.kg^{-1} represents the strictest critical values of the pseudototal content of Cu (for sheep); otherwise, the tolerable content 1.3 mg.kg^{-1} of the mobile species holds for the phytotoxicity. An identical value gives Prüeß (1992). In the BWSPA there are noticed critical values for fodder plants 1.0 mg.kg^{-1} of the mobile species (MN) and 2.4 mg.kg^{-1} for phytotoxicity.

Zinc

The exceeding of critical soil parameters leading to the phytotoxicity plant loads can be expected only in extreme conditions in accordance with the Figures 11 and 12. Only if the total content of Zn exceeds 700 mg.kg^{-1} the critical content of the mobile species (MN) sinks below the generic critical value 30 mg.kg^{-1} (Figure 11). Figure 12 shows that at average values of the mobilizable species

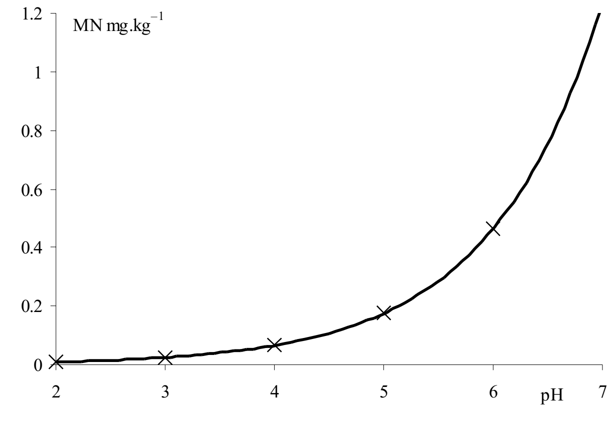


Figure 9. Dependence of the critical transfer values of Cu into triticale upon the mobile species (MN), content and pH in soils

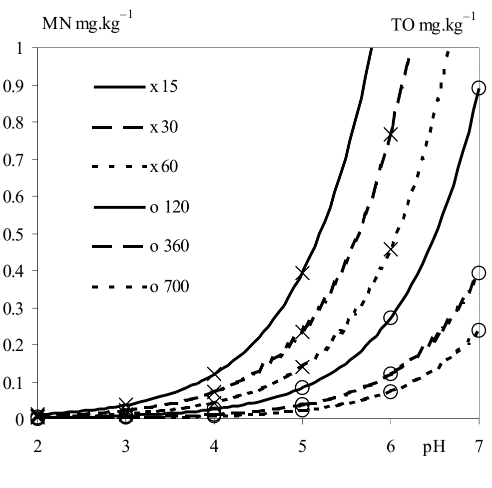


Figure 10. Dependence of the critical transfer of Cu into triticale upon the mobile species (MN) content at different levels of the total content of Cu in soils

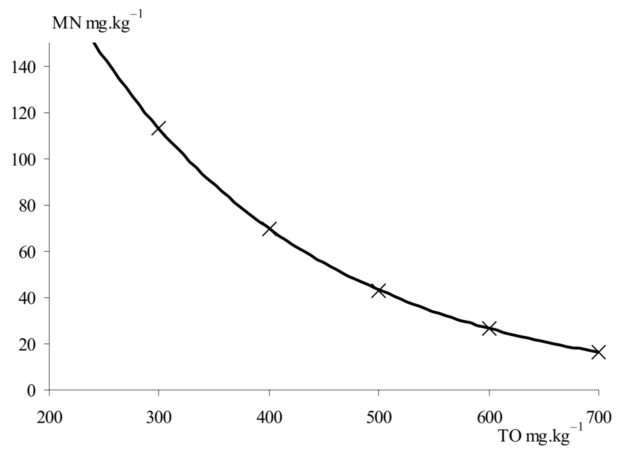


Figure 11. Dependence of the critical transfer of Zn into triticale upon the mobile species (MN) and total content (TO) of Zn in soils

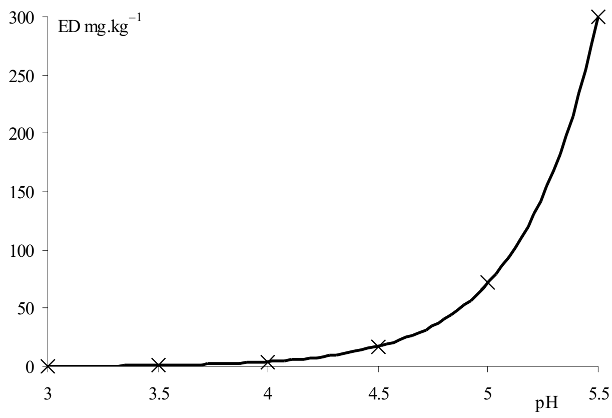


Figure 12. Dependence of the critical transfer of Zn into triticale upon the mobilizable species (ED) content and pH in soils

(ED) in soils (35 mg.kg^{-1}) critical values can be obtained only at pH less then 4.5, at the highest values of the set (300 mg.kg^{-1}) at pH 5.5.

The most sophisticated relations show that even at pH 4 and 90% solubility (ED/TO × 100) the critical total content of Zn is close to 2000 mg.kg^{-1} (Figure 13).

The soil critical value of the mobile species (MN) 2 mg.kg^{-1} for phytotoxicity is given in the GSPA. In the BWSPA and in criteria proposed by Prüeß (1992) values 5 mg.kg^{-1} for fodder plants and 10 mg.kg^{-1} for phytotoxicity are listed. In the BWSPA we find the following pseudo-total contents –150 mg.kg^{-1} for coarse textured soils at pH 5 and another soils at the pH 5–6, –200 mg.kg^{-1} at pH > 6.

Nickel

The critical values can be derived from the interactions pH – total content, which are displayed in Figure 14: pH 3 – 30 mg.kg^{-1}, pH 4 – 50 mg.kg^{-1}, pH 5 – 100 mg.kg^{-1}, pH 6.5 – 250 mg.kg^{-1}. Clay content mitigates critical transfer values of the total content but less distinctly at acid conditions (Figure 15).

The generic critical value of the mobile species (MN) can be surpassed only at very low pH values even if the total content is higher then 200 mg.kg^{-1}.

The GSPA takes for critical the total content (grasslands) 1900 mg.kg^{-1} and the content of the mobile species (MN) 1500 µg.kg^{-1} (phytotoxicity). The BWSPA proposes 1200 µg.kg^{-1} of the mobile species for phytotoxicity, Prüeß (1992) suggests 1000 µg.kg^{-1}.

Manganese

Testing values could be derived in accordance with the Figure 16 from the interactions among the total content and the content of potentially mobilizable (ED) and mobile (MN) species content. At average Mn contents and solubility the critical mobile species (MN) concentrations is close to 100 mg.kg^{-1}. These critical MN val-

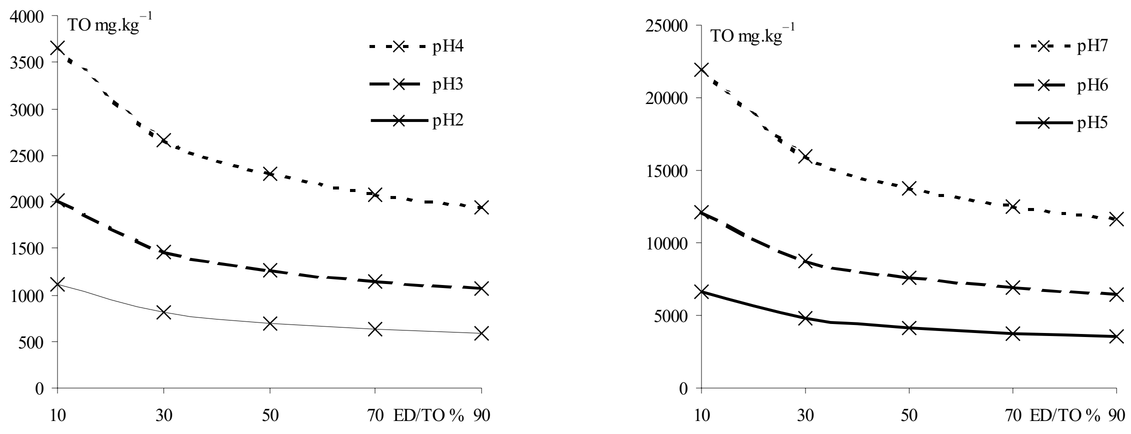
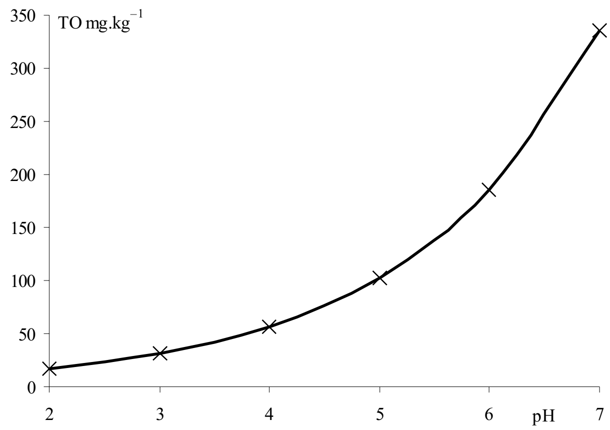


Figure 13. Dependence of the critical transfer of Zn into triticale upon the total content (TO) and Zn solubility (ED/TO × 100) at different pH levels in soils



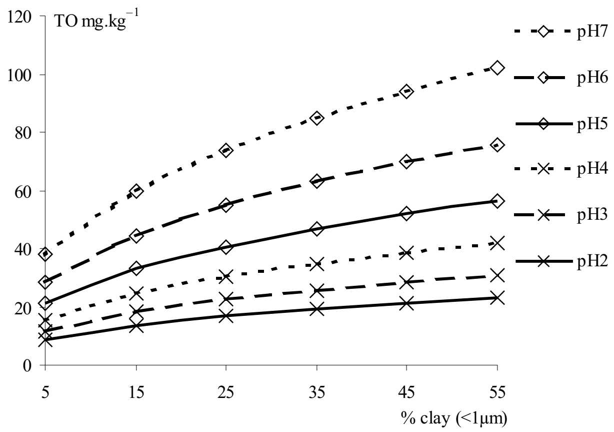


Figure 14. Dependence of the critical transfer of Ni into radish upon the total content (TO) of Ni and pH in soils

Figure 15. Dependence of the critical transfer of Ni into radish upon the total content of Ni and clay (< 1μm) content at different pH levels in soil

ues are growing more severe at higher total Mn contents.

The dependence of the critical plant transfer on the total and mobile species content at different pH levels is shown in Figure 17. The critical transfer values of the mobile species (MN) stricter than 100 mg.kg^{-1} can be exceeded either in acid soils or at higher total contents of Mn.

Critical values of Mn are lacking both in the GSPA and in BWSPA. Prüeß (1992) presents 30 mg.kg^{-1} of the mobile species.

Cobalt

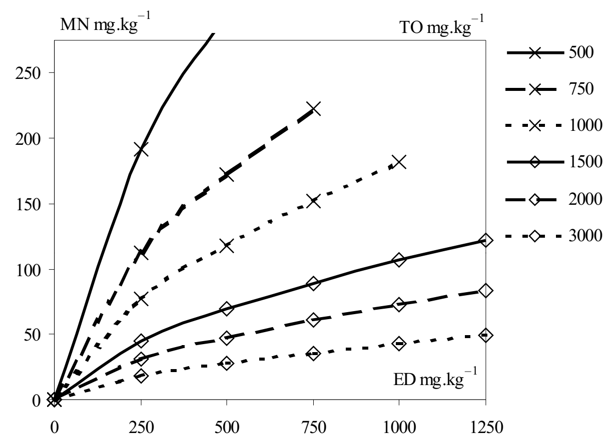
Cobalt is only rarely listed among pollutants. The more sophisticated approach derives critical transfer values from potentially mobilizable and mobile contents (Figure 18). Only Prüeß (1992) suggested 500 μg.kg^{-1} of the mobile species for phytotoxicity.

Beryllium, chromium, vanadium, and mercury

For these trace elements, only protective values have been proposed (Table 3).

Practical use of soil critical values

Generic soil critical testing values and protective critical values serve as the first piece of information. Thereafter the analysis of the interaction of soil characteristics leading to critical transfers into crops (graphical expression) has to be taken into consideration.



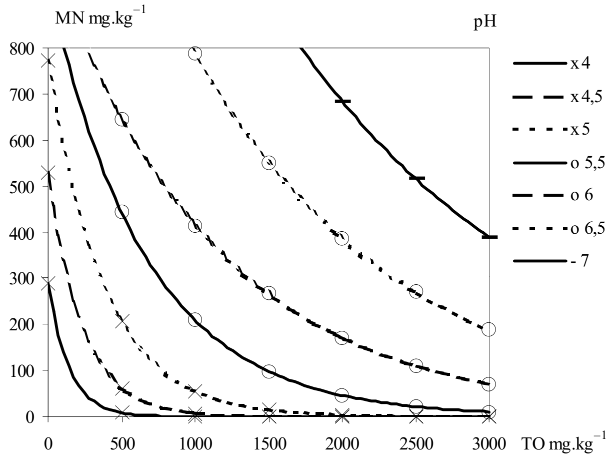


Figure 16. Dependence of the critical transfer of Mn into triticale upon the content of mobile (MN), mobilizable (ED) species and the total content (TO) of Mn in soils

Figure 17. Dependence of the critical transfer of Mn into triticale upon the mobile species (MN) and total content (TO) of Mn at different pH levels in soils

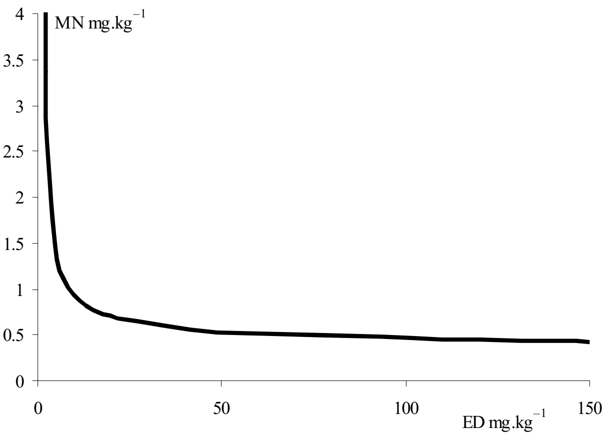


Figure 18. Dependence of the critical transfer of Co into triticale on the mobile (MN) and mobilizable (ED) species content of Co in soils

Critical values of the quality and quantity of the crop production must be proved on site.

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ABSTRAKT

Kritické hodnoty stopových prvků z hlediska transferové cesty půda – rostlina

Vývoj limitů ochrany kvantity a hlavně kvality rostlinné produkce probíhal od empirických hodnot k hodnotám kritickým, které jsou založeny na ekotoxicitě. Předkládáme řešení jejich odvození pomocí transferových funkcí. Byly vypočteny pomocí vícenásobné regresní analýzy. Dosazením kritických hodnot potravinářských, především pak pícninářských standardů či ukazatelů fytotoxicity jsou plněny soudobé ekotoxikologické požadavky. Při odvození kritických půdních hodnot upřednostňujeme vícefaktorové vztahy. Překročení odvozených hodnot musí být ověřeno stanovením nebezpečného transferu v terénu. Proto jsou označeny jako testovací hodnoty. Byly odvozeny pro Cd, Pb, As, Cu, Zn, Ni, Mn a Co. Pro většinu TEs byly stanoveny pouze ochranné hodnoty. Odrážejí minimální hodnoty, které zaručují pěstování rostlin bez jakýchkoli rizik. Experimentální údaje (z nádobových pokusů) byly srovnávány s výsledky získanými terénním pozorováním. Veškeré výsledky byly konfrontovány s hodnotami navrženými v Německu.

Klíčová slova: stopové prvky; ochrana kvality a kvantity rostlinné produkce; kritické půdní referenční hodnoty

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