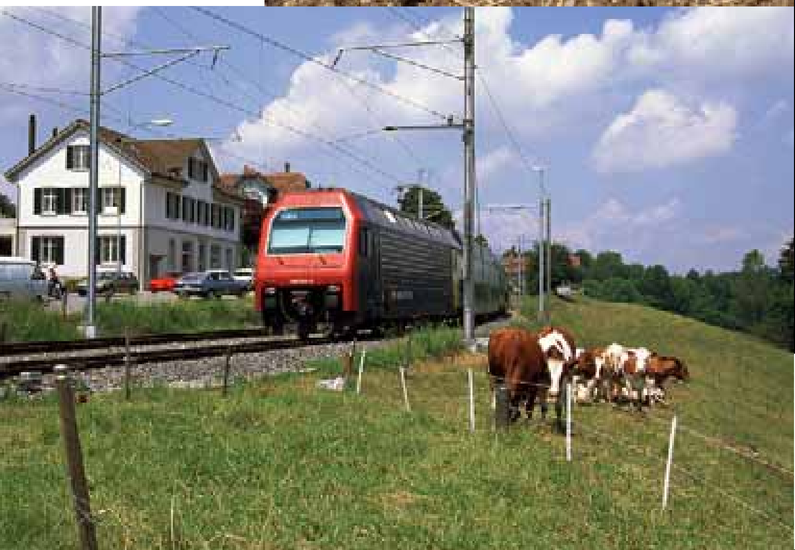
Environment in practice

# Manual on risk assessment and measures for polluted soils

## Risk assessment for soils



Swiss Agency for the Environment, Forests and Landscape
SAEFL

**Environment in practice**

# Manual on risk assessment and measures for polluted soils

## Risk assessment for soils

**Published by the Swiss Agency for the Environment, Forests and Landscape SAEFL**
**Berne, 2005**

## Legal status of this publication

*This publication is an implementation guide issued by SAEFL in its capacity as a supervisory authority, and is addressed primarily to the enforcement authorities. It seeks to clarify undefined legal concepts contained in the relevant Acts and ordinances so as to facilitate consistent enforcement practices. Authorities who give due consideration to these guides can safely assume that federal law is being correctly implemented. Alternative approaches are, however, permissible provided they comply with the legal requirements. Guides of this kind (also referred to as guidelines, guidance, recommendations, handbooks, enforcement aids, etc.) are published by SAEFL in the series entitled «Applying environmental law».*


## Issued by

Swiss Agency for the Environment, Forests and Landscape (SAEFL)
*SAEFL is an agency of the Federal Department of Environment, Transport, Energy and Communications (DETEC)*



## Authors

Reiner A. Mailänder,
Geotechnisches Institut AG, Zürich
Markus Hämmann,
Geotechnisches Institut AG, Zürich



## Expert team

Jürg Zihler, SAEFL, Berne
Johannes Dettwiler, SAEFL, Berne
Franz Borer, Amt für Umwelt, Solothurn
Anton Candinas, Swiss Federal Office for Agriculture
Frédi Celardin, Ecole d'Ingénieurs de Lullier, Jussy
André Desaules, Agroscope FAL Reckenholz, Zurich
Ursin Ginsig, Amt für Umwelt, Frauenfeld
Rolf Gsponer, Amt für Landschaft und Natur, Zurich
Armin Keller, Agroscope FAL Reckenholz, Zurich
Elmar Kuhn, Kantonales Labor Aargau, Aarau
Daniel W. Müller, Amt für Umwelt, Frauenfeld
Guido Schmid, Amt für Umweltschutz,
St. Gallen
Rainer Schulin, Institute for Terrestrial Ecology (ITE),
ETH Zurich
Urs Ziegler, SAEFL

## Suggested form of citation

MAILÄNDER R.A., HÄMMANN M. 2005: *Manual on risk assessment and measures for polluted soils.* Environment in practice. Swiss Agency for the Environment, Forests and Landscape, Bern. 9 pp.

## SAEFL consultant

Jürg Zihler, Chef Sektion Boden
Johannes Dettwiler, Sektion Boden
Christoph Zäch, Chef Abteilung Recht

## Translations

Peter Case, Heimenschwand b. Thun

## Design

Ursula Nöthiger-Koch, Uerkheim

## Cover illustration

SAEFL/AURA und SAEFL/Docuphot

## Orders

SAEFL
Documentation
CH-3003 Berne
Fax +41 (0)31 324 02 16
docu@buwal.admin.ch
www.environment-switzerland.ch/publications

Order number:
VU-4817-E
This publication is also available in German, French and Italian (VU-4817-D/VU-4817-F/VU-4817-I).

# Table of contents

# Abstracts

**E**

This handbook indicates how the possible risk to humans, animals or plants (subject of protection) as a result of soil pollution levels between trigger values and clean-up values can be measured. A distinction is made between the three types of land use : plants for human consumption (food plants), plants for animal consumption and uses with possible direct uptake. The procedure always uses a 2-stage process : soil impact analysis (transfer of pollutant to humans, animals or plants as subjects of protection) and impact evaluation (allocation to a risk category). In general, an expert system is used for impact analysis and evaluation which permits a simplified risk assessment on the basis of a point scale (indicator). In cases where the expert system is inadequate, approaches permitting a more detailed risk assessment are presented. In addition, the handbook describes risk reduction measures.

Keywords :
Soil protection,
risk assessment,
health risks,
trigger values,
soil pollutants

**D**

Für Schadstoffbelastungen des Bodens zwischen Prüf- und Sanierungswerten zeigt dieses Handbuch auf, wie eine mögliche Gefährdung für Menschen, Tiere oder Pflanzen (Schutzgüter) abzuschätzen ist. Dabei wird unterschieden zwischen den drei Nutzungsarten Nahrungspflanzenanbau, Futterpflanzenanbau und Nutzungen mit möglicher direkter Bodenaufnahme. Das Vorgehen umfasst immer zwei Schritte, nämlich die Belastungsanalyse (Transfer von Schadstoffen zu den Schutzgütern Mensch, Tiere oder Pflanzen) und die Belastungsbewertung (Zuweisung der Gefährdungskategorie). Im Regelfall kann für Belastungsanalyse und -bewertung jeweils ein so genanntes Expertensystem verwendet werden, das eine vereinfachte Gefährdungsabschätzung mit Hilfe eines Punktesystems erlaubt. Für Einzelfälle, in denen die Beurteilung durch das Expertensystem nicht ausreicht, werden Möglichkeiten für eine detailliertere Gefährdungsabschätzung dargestellt. Das Handbuch beschreibt zudem Massnahmen zur Gefährdungsabwehr.

Stichwörter :
Bodenschutz,
Gefährdungs-
abschätzung,
Gesundheits-
gefährdung,
Prüfwerte,
Bodenschadstoffe

**F**

Le présent manuel montre comment évaluer une menace potentielle pour l'homme, les animaux ou les plantes (biens à protéger) lorsque des sols sont pollués à des teneurs comprises entre seuil d'investigation et valeur d'assainissement. Trois utilisations du sol sont considérées : cultures pour l'alimentation humaine (cultures alimentaires), cultures pour l'alimentation animale (cultures fourragères) et utilisation avec risque par ingestion. La procédure comporte toujours deux étapes, c'est à savoir l'analyse des atteintes au sol (transfert du polluant au bien à protéger – homme, animaux ou plantes) et l'évaluation du degré de pollution (attribution à une catégorie de risque). En règle générale, un système expert est utilisé pour l'analyse et l'évaluation, système qui permet une estimation simplifiée de la menace à l'aide d'indices. Pour les cas particuliers pour lesquels le système expert n'est pas suffisant, le manuel présente des approches permettant une évaluation plus détaillée. Il décrit enfin les mesures à prendre pour éliminer la menace.

Mots-clés :
protection du sol,
évaluation de la
menace,
risques pour le santé,
seuils d'investigation,
polluants du sol

**I**

Il manuale illustra come valutare i potenziali pericoli per l'uomo, la flora o la fauna (beni da proteggere) quando il tenore delle sostanze nocive nel suolo si situa tra i valori di guardia e quelli di risanamento. Si distinguono tre forme di utilizzazione del suolo: colture alimentari, colture foraggere e utilizzazioni con possibile assunzione diretta di terra. La valutazione comprende sempre due fasi: l'analisi dell'inquinamento (trasferimento delle sostanze nocive al bene da proteggere – uomo, animali o piante) e la valutazione dell'inquinamento (attribuzione a una categoria di rischio). Di norma, dette fasi possono essere eseguite applicando un cosiddetto sistema esperto, il quale permette di effettuare una stima semplificata del potenziale rischio con l'aiuto di un modello a punti. In casi particolari per i quali l'applicazione del sistema esperto è insufficiente, il manuale offre delle soluzioni che permettono di valutare in maniera dettagliata il potenziale rischio. Infine, vengono descritte delle misure idonee a prevenire il pericolo.

Parole chiave :
protezione del suolo,
valutazione del pericolo,
pericolo per la salute,
valori di guardia,
sostanze nocive nel suolo

# Foreword

Soils that are heavily polluted with contaminants can represent a risk to humans and the environment. This is especially so when the ground is used by children as a playing area, when animals graze on it, or when foodstuffs or fodder produced on it are consumed. In such cases, soil protection legislation – represented in the main by the *Ordinance on Impacts on the Soil* of 1998 (OIS) – obliges the cantons to determine whether an anticipated risk is in fact present. If so, they must restrict the use concerned, or prohibit it.

The Manual provides a methodology for the performance of risk assessment, and was prepared by a broad-based team of specialists. Moreover, it draws on acknowledged scientific sources in Switzerland and abroad, including comprehensive databases derived from chemical soil analysis. Our particular thanks are due to the German Federal Agency for the Environment in Dessau and to the regional German governments, who have provided valuable scientific documentation underpinning the methods of assessment and evaluation aimed specifically at the application of measures.

The health of humans, animals and plants is a central protection objective, and the Manual represents a contribution to upholding it. The work is founded on current knowledge and experience. Future applications will doubtless yield additional insights and experience, thereby furthering its effectiveness in promoting chemical soil protection.

The Manual, which was successfully tested in a case of soil pollution in the neighbourhood of a metal works, is now available to all concerned parties. I wish to warmly thank all those who have contributed to the success of the publication.

Swiss Agency for the Environment,
Forests and Landscape

*Georg Karlaganis*

*Head of the Department for Substances,*
*Soil, Biotechnology*

# 1 Introduction

## 1.1 Purpose

Polluted soils can represent a hazard to the health of humans, animals or plants. The assessment of polluted soils is based on the trigger and clean-up values laid down in the *Ordinance relating to Impacts on the Soil of 1 July 1998l (OIS; SR 814.12).* When the trigger values are exceeded, current knowledge and experience indicate that a definite risk to humans, animals or plants may exist. In this case, the cantonal enforcement authorities must assess whether the soil pollution in fact represents a definite risk. If this is the case, they must restrict its use to such an extent that the hazard no longer exists. Where the clean-up values are exceeded, the use concerned must be prohibited or the soil remediated.

The Manual specifies the steps required to assess the polluted soil as follows:
- what is to be investigated to clarify the hazard;
- how to assess whether a definite risk exists or not in particular cases;
- what measures are to be taken if a definite risk exists.

The Manual aids in harmonising enforcement of the OIS, and thereby contributes towards legal security. It is addressed both to professionals in the cantonal enforcement authorities, and to engineering and environmantal consultants.

## 1.2 Contents and structure

The Manual is divided into the following parts:
- **Chapter 2** concerns the legislative basis and the relationship to the Contaminated Sites Ordinance of 26 August 1998 (OCS; SR 814.680).
- **Chapter 3** explains the general procedure for risk assessment.
- **Chapters 4–6** show how the hazard assessment is performed for the uses food plant cultivation, fodder plant cultivation and uses with possible direct soil ingestion.
- **Chapter 7** specifies the procedure when no regulatory values are available (trigger value, clean-up value).
- **Chapter 8** describes the measures to be taken to reduce risk.
- The **annex** contains further basic data and additional information needed for risk assessment. **Annexes 1** and **2** will be found to be particularly useful. The case studies in **Annex 1** are designed to assist the user in applying risk assessment procedures based on typical cases. **Annex 2** contains basic information on the hazards to humans, animals and plants for pollutants specified in the OIS.
- Pre-programmed **spreadsheets** permitting simple performance of risk assessments round up the Manual.[1]

---

[1] cf. excel format: http:\\www.environnement-suisse.ch→thèmes→sol→mise en œuvre de l'OSol→ manuel évaluation de la menace.

# 2 Legal basis

## 2.1 Scope of the Manual

The Manual applies to all soils dealt with in Art. 7 Para. 4bis *Law relating to the Protection of the Environment of 7 October 1983 (LPE, SR 814.01).* The OIS, which is based on the LPE, concerns those areas in which the trigger value is either known to be exceeded, or where there is justification to assume this. In such areas, the polluted soil represents a definite risk to humans, animals or plants. Moreover, if the clean-up value is exceeded for a particular use, this cannot be continued without risk (cf. Chap. 2.4), so that in this respect no risk assessment is necessary.

**Relationship to the OCS**

In Art. 2 *of the Ordinance relating to the Rehabilitation of Contaminated Sites of 26 August 1998 (Contaminated Sites Ordinance, OCS; SR 814.680)* it is stated that contaminated sites are those whose pollution originates from waste, and are restricted to a particular area. They comprise waste disposal, industrial and accident sites. For the determination of the need for clean-up and required measures for contaminated sites, soil protection legislation (cf. Arts. 34 and 35 LPE; detailed in the OIS) – and in consequence the Manual – are only applicable in the following circumstances (cf. Arts. 12 and 16 let. c OCS):

- The impact of soils that belong to a contaminated site on humans, animals and plants.

However, the procedure itself is based on the OCS.

In consequence, the Manual is not applicable to the examination and assessment of other impacts arising from contaminated sites to which the OCS also applies (i.e. impacts on ground and surface waters, and room or ambient air). In these cases, procedures are based solely on the OCS and related guidelines.

The decisive factor in deciding between the OCS and the OIS is therefore not *where* a soil lies, but *which* protection objective is being pursued, i.e. protection of ground and surface waters, and protection from air pollution, to which the OCS applies; or protection of the soil (long-term conservation of soil fertility, with a view – among other things – to avoiding a risk to humans, animals or plants), to which the OIS applies.

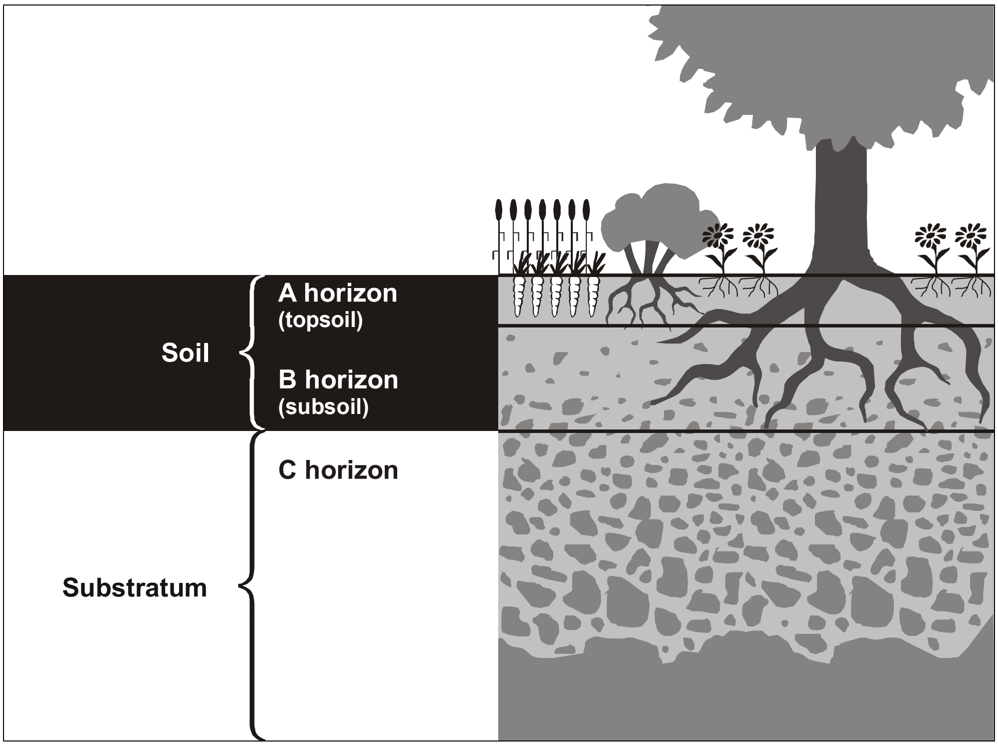
## 2.2 Definitions

Soil is defined as the **unsealed top layer of land where plants can grow** (legal definition of soil in the LPE; cf. also Fig. 1). A chemical impact on the soil is defined as pollution of the soil through naturally occurring or man-made substances (pollutants; cf. Art. 2 Para. 2 OIS). These are assessed according to the OIS based on guide, trigger and clean-up values.

## 2.3 Guide values and measures

The guide values indicate the pollution level above which, in the light of current scientific knowledge or experience, soil fertility is no longer guaranteed in the long term (cf. Art. 35 Para. 2 LPE). If it has been established, or is anticipated, that such impacts will adversely affect the fertility of the soil in certain regions, the cantons must make provision for monitoring soil impacts. In addition, the cantons must determine the source of the impact and consider measures to prevent its further increase (emission control; cf. Art. 8 OIS).

Fig. 1: The subject of the Manual is the area designated «soil».




**Topsoil = A horizon** (usually referred to in common parlance as «humus»):
Weathered mineral layer that is enriched with organic substance, with intensive soil life, permeated with roots, loose and usually dark brown in colour.

**Subsoil = B horizon:**
Layer that is usually less heavily weathered, with noticeably less soil life, less densely permeated with roots, with little organic content, mostly lighter in colour (rust to light brown) and usually of higher volumetric density than the A horizon.

**Substratum = C horizon:**
Original mineral material that is not weathered, or hardly so, with hardly any soil life, containing few roots and without organic material; no longer regarded as soil.

## 2.4 Trigger values and measures

Trigger values indicate for a given type of use the level of impacts on the soil, which, if exceeded, could present a hazard to humans, animals or plants, according to current scientific knowledge and experience (cf. Art. 2 Para. 5 OIS). They serve to indicate whether restrictions on soil use are necessary. A risk is deemed to be «definite» if it is actually realised at some point in time during the normal course of events, i.e. an impairment to health and the environment occurs.

If in a given region the trigger value has been exceeded, the cantons must determine whether the impact on the soil represents a definite risk to humans, animals or plants. If this is the case, the cantons must restrict soil use as far as this is necessary to eliminate the hazard (cf. Art. 9 OIS). Where the trigger value is exceeded, the guide value is always substantially exceeded. Here, more stringent measures as specified in Art. 8 OIS must be taken, namely to determine the source of the impact and to prevent its further increase.

Trigger values are available for the uses *cultivation of food plants, cultivation of fodder plants* and *uses with possible direct soil ingestion* (cf. Annex 1 nb. 12 OIS). If guide values are not available, a case-by-case assessment is made as to whether the polluted soil represents a definite risk to the health of humans, animals or plants (cf. Art. 5 Para. 2 OIS).

## 2.5 Clean-up values and measures

The clean-up values indicate the pollution level above which, in the light of current scientific knowledge or experience, certain uses are not possible without incurring a risk to humans, animals or plants (cf. Art. 35 Para. 3 LPE).

Where the clean-up values are exceeded in an area, the cantons must prohibit the respective uses. In areas designated for horticultural, agricultural or forestry use under development planning, they must prescribe measures to reduce the impact on the soil sufficiently far below the clean-up values to permit the intended (customary) cultivation of the site without incurring a risk to humans, animals and plants (cf. Art. 10 OIS).

Clean-up values exist for the use categories agriculture and horticulture, home gardens, allotments and children's playgrounds (cf. Annex 1 nb. 13 OIS). If clean-up values are not available for certain soil uses, a case-by-case evaluation is made of whether the impact on the soil represents a definite risk to the health of humans, animals or plants (cf. Art. 5 Para. 3 OIS).

## 2.6 Responsibility for enforcement

Art. 36 LPE stipulates that, except as provided for in Art. 41 LPE, the responsibility for enforcement in general, and for soil protection in particular, lies with the cantons. If, however, another federal law is being enforced by a federal authority (e.g. DCPS, SACA, SAT) in accordance with Art. 41 Para. 2 LPE, this authority is directly responsible for enforcing the LPE.

For this reason, soil protection according to LPE for firing ranges and firing installations must be enforced by the DCPS agency responsible for the enforcement of the *Federal Law relating to the Army and the Military Administration of 3 February 1995 (Military Law, ML; SR 510.10).*

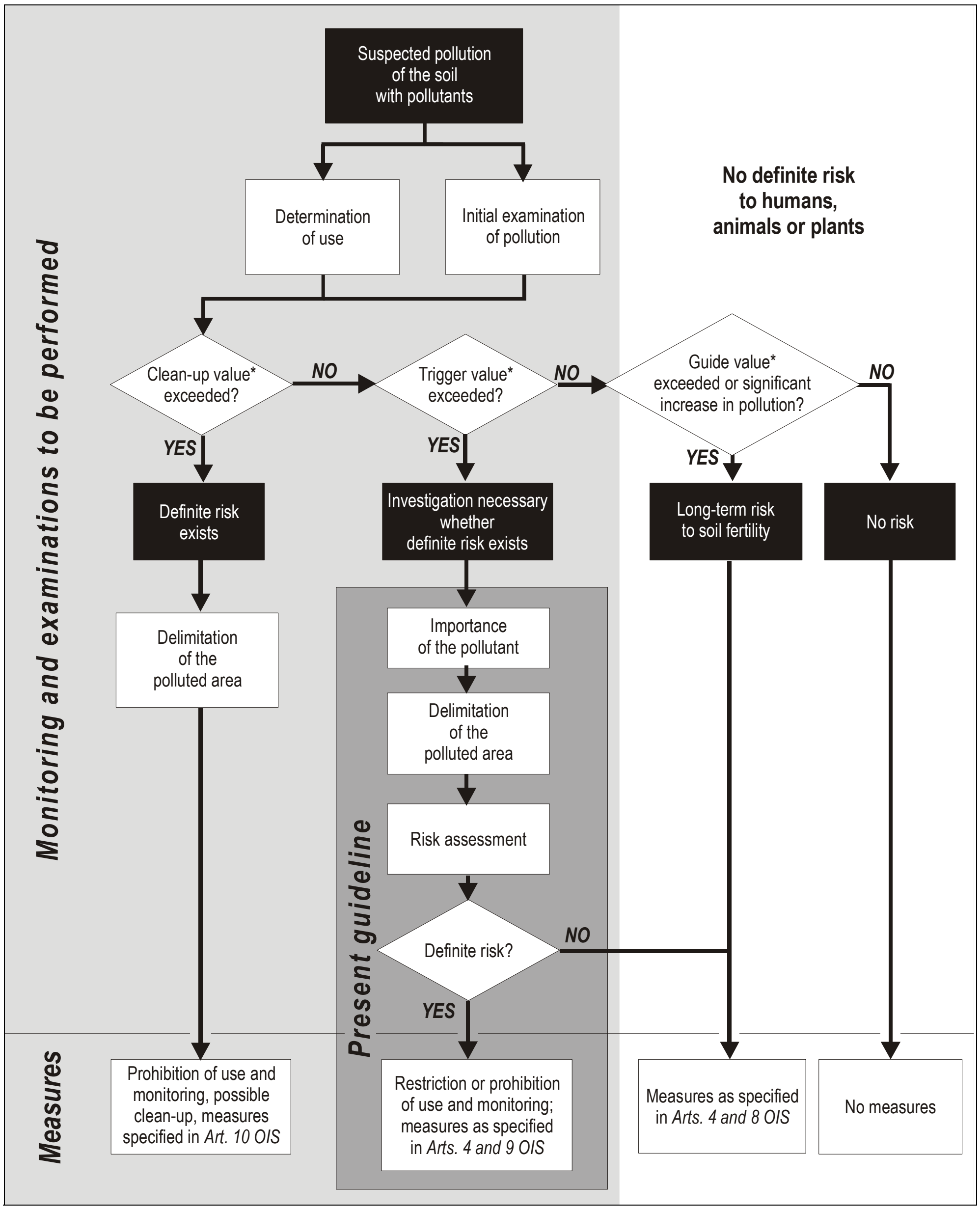
This also applies to risk assessment as specified in Art. 9 OIS. Therefore at all points where the Manual makes reference to cantonal responsibility, this applies in a similar way to the DCPS enforcement authority in applying the ML (cf. Art. 126 ML).

The responsibility of the DCPS for enforcing soil legislation is then, and only then, transferred to the cantons when a specified firing range is released from military use and is no longer subject to the ML, and thus the terrain is returned to civil use.

Art. 41 LPE requires that the federal authorities shall work together with the cantonal authorities in enforcing the LPE.

# 3 Procedure

Fig. 2: Procedure for polluted soils as specified in soil legislation and function of the Manual. [*In the absence of regulatory values according to OIS, see Chap. 7].




## 3.1 Procedures for voluntary restrictions of use

Where those concerned agree to voluntary restrictions of use, the risk assessment may be dispensed with provided the protection objectives can in this way be met. In this event, conformance with the restrictions of use is confirmed in binding form by the owners of the property. The form the confirmation should take is decided seperately in each case.

## 3.2 Determination of use

**Types of use**

The use to which an area is put determines the exposure paths via which humans, animals and plants may be subject to a definite risk from pollutants. Annexes 1 and 2 OIS specify the following uses in relation to the trigger values:

- Cultivation of food plants (arable farming, vegetable, fruit and wine cultivation, home gardens and allotments);
- Cultivation of fodder plants (fodder production, meadow for cutting, pasture, pasture for cutting);
- Uses with possible direct soil ingestion (home gardens and allotments, children's playgrounds, kindergartens, school grounds, green areas, sports grounds).

**Present and future uses**

The following information must be recorded for polluted soils:

- The current use (for risk assessment);
- Planned or possible further uses as laid down in development planning. These are necessary for the assessment of possible future risks and to determine the soil monitoring requirements. A typical example of this are polluted agricultural areas that are to be converted to residential use (rezoning).

## 3.3 Importance of the pollutant

**Exposure paths and subjects of protection**

The importance of a pollutant with regard to the risk to the respective subjects of protection, including humans, must be determined. The exposure paths differ depending on the use and pollutant (see details on common pollutants in Annex 2). Risk assessment differs depending on the particular use (cf. Chap. 4–6).

### 3.3.1 Importance of pollutants in food plant cultivation

The use category food plant cultivation comprises the production of plant products for human consumption. In this, there is only one exposure path (cf. Tab. 1).

Tab. 1: Exposure path in food plant cultivation.

| Exposure path | Pollutant transfer |
|---|---|
| Uptake by food plants (via roots and leaves) | soil→*[soil solution→]*plant→humans |

A pollutant is important with regard to the risk to humans through consumption of food plants if the two following conditions are fulfilled (cf. Annex 2):

- The food plant takes up pollutants, adsorbs them or is polluted with soil.
- The pollutant or its conversion products, if any, are toxic to humans (human toxicity).

### 3.3.2 Importance of pollutants in fodder plant cultivation

The use category fodder plant cultivation concerns the production of plant products for the consumption by livestock, and comprises both arable uses (e.g. maize, fodder cereals, fodder beet) and green areas (e.g. pasture, meadow for cutting). In this respect, the pollutants can be a risk both to the livestock itself, and to humans who consume the animal products. To assess whether a pollutant is important in connection with fodder plant cultivation, the exposure paths shown in Tab. 2 and the human and animal subjects of protection must be considered.

Tab. 2: Exposure paths in fodder plant cultivation.

| Exposure path | Pollutant transfer |
|---|---|
| Root uptake | soil→soil solution→plant→animals→humans<br>soil→soil solution→plant→animals |
| Crop soiling<br>(with so-called ‹earthy› pollutants) | soil→plant→animals→humans<br>soil→plant→animals |
| Direct oral ingestion | soil→animals→humans<br>soil→animals |

**Risk to animals**

The transfer of pollutants to animals occurs via grazing of plants, by direct oral soil ingestion, or through crop soiling. Depending on the type of livestock and fodder, the percentage of direct oral soil ingestion represents 0–30% of the weight of the fodder (cf. Tab. 13).

A pollutant represents a risk to animals through root uptake if conditions **1** and **2** are fulfilled:

**1** The fodder plant takes up the pollutant.
**2** The pollutant or its conversion products, if any, are toxic to the animal (zoo toxicity).

A pollutant represents a risk to animals through direct oral soil ingestion or through soiling of the fodder if conditions **3** and **4** are fulfilled:

**3** The pollutant is ingested by the animal concerned by direct oral soil ingestion or by soiling of the fodder.
**4** The pollutant or its conversion products, if any, are toxic to the animal (zoo toxicity).

**Risk to humans**

A pollutant is a risk to humans through the consumption of polluted animal products if conditions **1**, **5** and **6** or **3**, **5** and **6** are fulfilled:

**5** The pollutant accumulates in the animal product.
**6** The pollutant or its conversion products, if any, are toxic to humans (human toxicity).

The following information is therefore decisive:

- Livestock affected: e.g. cattle, sheep, pigs;
- Type of feeding for each animal category concerned: e.g. grazing, feeding of hay, fodder cereals and other intensive fodder.

### 3.3.3 Importance of pollutants in uses with possible direct soil ingestion

For uses with possible direct soil ingestion, pollutant transfer occurs via a single exposure path (cf. Tab. 3).

Tab. 3: Exposure path for uses with possible direct soil ingestion.

| Exposure path | Pollutant transfer |
| --- | --- |
| Direct oral ingestion | soil→humans |

**Risk through direct soil ingestion**

A pollutant is important with regard to the risk to humans through direct soil ingestion if:
- Humans ingest the pollutant directly through contact with the soil;
- The pollutant is toxic to humans (human toxicity).

## 3.4 Delimitation and analysis of soil impact

**Horizontal and vertical extent**

Determination must be made of the horizontal and vertical extent of soil pollution. Sampling is performed in accordance with the *Manual – Sampling and sample pretreatment for soil pollutant monitoring* (SAEFL 2003). It must be performed by personnel qualified in soil science. Core samples must be taken at selected points. Sampling is performed at fixed depth levels, which should be chosen to be not less than 5 cm to assure reproducibility. The depth levels are laid down in relation to the expected impact (exposure hypothesis), the exposure path and the subjects of protection affected, i.e. humans, animals or plants (Annexes 1 and 2 OIS).

**Soil analyses**

The analyses of the soil required depend on the respective use (cf. Chap. 3.2 and Annexes 1 and 2 OIS). For the purposes of risk assessment, in addition to the pollutant content, further soil characteristics must be determined. This aspect must be considered in planning the sampling procedure.

Suitable for this are all soil analysis methods that have been calibrated against the standard OIS method (cf. Annexes 1 and 2 OIS), and which consistently give comparable and reproducible results. Suitable methods include physical methods of analysis in line with current technology (e.g. X-ray fluorescence).

The following data apply to all categories of use:
- For inorganic pollutants, the total content and, where appropriate, the soluble content, as specified in Annex 1 OIS. In general, the total content specified in the OIS will suffice (expert systems, cf. Chap. 3.5.2).
- For organic pollutants, total content as specified in Annex 2 OIS.

For the uses food and fodder plant cultivation, the following additional data on soil characteristics must be determined:

- pH value;
- Content of *organic substance («humus content»);* for organic pollutants, an analytical determination, or at least an estimate, in the categories 0–2, 2–8, 8–15 and >15% is recommended (cf. AGROSCOPE FAL RECKENHOLZ 1997, AG BODEN 1994);
- Granulate size distribution and, in addition, at least a rough estimate of the clay content of the fine earth fraction using a finger test (cf. AGROSCOPE FAL RECKENHOLZ 1997, AG BODEN 1994);
- If necessary, additional determination of the lime content and the effective cation exchange capacity «$CEC_{eff}$». These values can help to improve the assessment of the current availability of the pollutant and future variations in it.

## 3.5 Risk assessment

### 3.5.1 General procedure

If the examination of the soil pollution confirms that trigger values are exceeded in an area, and the polluted soil may therefore represent a definite risk to humans, animals or plants, a risk assessment must be performed (exception: cf. Chap. 3.1). The procedure is performed as given in Chapters 4–6 for each use category. The principles and procedures applying to all forms of use are briefly discussed in the following.

**Risk assessment: always performed in two steps**

The risk assessment comprises an ***impact analysis*** and an ***impact evaluation:***

- In the *impact analysis,* the impact of a pollutant on humans, animals or plants is determined (transfer to these subjects of protection).
- The *impact evaluation* determines whether the impact represents a risk based on specific criteria.

The evaluation criteria in the Manual are based on maximum values specified in legislation and on scientifically recognized, toxicologically established threshold values (maximum content in foods and animal feedstuffs; maximum tolerable ingestion rates in humans and animals). To perform the evaluation, risk categories are assigned to the impacts as given in Tab. 4.

Tab. 4: Assignment of risk categories to impacts.

| Impact | Risk category |
|---|---|
| No significant increase in pollutant content (food/fodder) or in pollutant ingestion (humans and animals). | → No definite risk |
| Significant increase in pollutant content (food/fodder) or pollutant ingestion (humans and animals). However, no cases found of legislative maximum content or scientifically recognized, toxicologically established, threshold values being exceeded. | → Definite risk possible |
| Legislative maximum content or scientifically recognized, toxicologically established, threshold values (food/fodder), or pollutant ingestion by humans and animals exceeded. | → Definite risk |

### 3.5.2 Risk assessment using expert systems

For each use category, the Manual provides a so-called expert system that enables a risk assessment to be performed with a minimum of effort (cf. Chaps. 4.1, 5.1 and 6.1). With expert systems, points are assigned to the individual parameters and these summed to give the *risk score.* Finally, the risk categories are assigned based on the score.

**When are expert systems suitable?**

The expert systems are calibrated for pollutant concentrations lying between the trigger and clean-up values, and are only applicable in this range. They are based on total pollutant content in the soil, because on the one hand these data are usually available from previous investigations, and on the other hand, the soluble content is not decisive for all pollutants (e.g. lead). In these cases, therefore, the OIS does not specify regulatory values for soluble content. Otherwise, if merely the trigger values for the soluble content are exceeded in an area, or if data are only available on the soluble content, more detailed investigations are required (cf. Chaps. 3.5.3, 4.2, 5.2 and 6.2).

Usually, a risk assessment using expert systems is justified. Subsequently, measures are assigned in the same way as with the detailed procedure (Chap. 3.5.3), since both procedures are based on the same evaluation criteria. However, the expert systems are simplified through the application of the point system, and this unavoidably leads to greater uncertainty owing to the complexity of the soil system (cf. Chap. 3.7 and Annex 9). Thus in special cases, although the risk category *«definite risk»* may be assigned by the expert system, it is still possible that the maximum content and/or the threshold values are not exceeded.

Finally, alongside the risk assessment, the expert systems enable an initial (rough) assessment to be made of the effects of uncertainties in individual parameters («factors»). To do so, the factors can be varied and the effects on the risk assessment determined (sensitivity analysis). Furthermore, this enables measures best suited to counteracting the current hazardous situation (measure scenarios) to be identified.

To permit simplified performance of risk assessments using expert systems, preprogrammed ***spreadsheets*** are available.[2]

[2] cf. excel format: http:\\www.environnement-suisse.ch→thèmes→sol→mise en œuvre de l'OSol→ manuel évaluation de la menace.

### 3.5.3 Risk assessment by means of detailed investigation

A detailed investigation is required particularly where large uncertainties are present (e.g. unreliable input data). Furthermore, it enables persons who are not in agreement with measures decided on by the authorities to perform an assessment of their own (cf. Chaps. 3.6 and 8).

Here, the following rule applies:

**An assessment based on expert systems remains valid unless a detailed investigation indicates that it should be amended.**

## 3.6 Determination of measures

**Which measures apply to which risk category?**

Whenever the trigger values are exceeded in a given region, it is essential that measures be taken. Where the risk assessment indicates a (possible) definite risk, risk reduction measures must be taken. If the risk assessment shows no definite risk, the area concerned must nevertheless be monitored as specified in Art. 4 Para. 1 OIS, since when the trigger value is exceeded, it must be assumed that – at least in the long term – there is a risk to soil fertility (guide values significantly exceeded). Note also that the risk situation may change if the form of use is altered.

The determination of measures is described in detail in Chapter 8. In general, the assignment of measures to the risk category is based on Tab. 5.

Furthermore, in determining measures, the special conditions of the case at hand – where these have not already been included in the risk assessment procedure – must be taken into account. These can make necessary a modification of the measures (cf. Chap. 8.1.2).

Tab. 5: Assignment of measures to risk categories.

| Risk category | Measures |
|---|---|
| No definite risk | → Monitoring (Art. 4 Para. 1 OIS) and emission control (Art. 8 OIS) |
| Definite risk possible | → Recommendations on form of use; additional monitoring (Art. 4 Para. 1 OIS) and emission control (Art. 8 OIS) |
| Definite risk | → Restrictions and prohibitions of use, possible clean-up; additional monitoring; (Art. 4 Para. 1 OIS) and emission control (Art. 8 OIS) |

## 3.7 Results (uncertainties)

### 3.7.1 Preliminary comments

The objective of a risk assessment is to determine the effects of soil pollution on the subjects of protection of humans, animals or plants as precisely as possible. Risk assessment is performed in two stages: *impact analysis* and *impact evaluation* (cf. Chap. 3.5.1).

The entire procedure for risk assessment is founded on current knowledge and experience. This statement applies both to the effects of pollutants on the health of humans and animals, and to the processes by which pollutants are transferred to the subjects of protection of human, animals or plants. The status of knowledge differs depending on the pollutant and process, and consequently, the assessment systems are subject to uncertainty (cf. Annex 5). This is particularly the case for the heavily simplified expert systems. The expert systems were therefore designed to embody the precautionary principle required by Swiss environmental legislation, and thus lie on the «safe side».

In estimating the value of parameters that are not measurable, or only so with difficulty, and in taking account of the special conditions of each case, the assessment of the person performing the analysis and their professional qualification play a substantial role. It is particularly difficult to assess the impact of special conditions. Where the special conditions result in a modified assessment, it is important to ensure that they in fact cause a significant alteration of the risk situation (see case study: kindergarten playground, Annex 1 C).

Furthermore, the influence of uncertainties on the result of the risk assessment and its magnitude should, if possible, be assessed. However, since the uncertainties are very difficult to quantify, this is no simple matter. To do so, analytical methods taking account of the variability of parameters may be used (Monte-Carlo methods, fuzzy logic), enabling their influence to be quantified (e.g. MOSCHANDREAS & KARUCHIT 2002, GUYONNET *et al.* 2003).

### 3.7.2 Impact analysis

Significant difficulty is encountered in estimating the pollutant transfer soil–animals–humans and soil–plants (impact analysis). The transfer depends on numerous parameters and the often complex interaction between them. The final result of risk assessment therefore depends on various factors and methods that are subject to numerous sources of uncertainty. These are in particular:

***Natural uncertainties***
- spatial and temporal variation of measured data

***Data uncertainties (measured data)***
- sampling and sample preparation (cf. Chap. 3.4);
- laboratory analyses (soil, plants, cf. Chap. 3.4).

***Uncertainties in accounting for and describing processes***

- estimation of parameters that are not measurable, or only so with difficulty, e.g. frequency of use of a playground (cf. Chap. 6.1);
- assessment systems, in particular expert systems (cf. Chaps. 4.1, 5.1 and 6.1);
- weighing up of special conditions in deciding on measures (cf. Chap. 8.1.2).

***Note on sampling:*** Risk assessment requires the determination of soil pollution, involving uncertainties in sampling, sample preparation and laboratory analysis. The problems in connection with sampling and sample preparation are set out in the Manual – Sampling and sample pretreatment for soil pollutant monitoring (SAEFL 2003). The greatest uncertainty stems from the spatial variability of the pollution (over the area examined and among the samples). The uncertainties in laboratory analysis may generally be well assessed from the yearly inter-laboratory analyses (AGROSCOPE FAL RECKENHOLZ) required by the OIS. Notes on the uncertainties incurred in comparing measured data with maximum concentrations and regulatory values are given in Annex 5 and DESAULES (2004).

### 3.7.3 Impact assessment

Impact assessment is performed using the maximum content laid down in legislation, together with scientifically recognized, toxicologically established, threshold values. Impact assessment represents the least source of uncertainty within the total risk assessment procedure.

In conjunction with the conservative procedure chosen (tendency towards the «safe side»), the prevention principle can lead in certain circumstances to overestimating the risk. For this reason, assessments using expert systems are not to be regarded as conclusive (cf. Chap. 3.5.2). Furthermore, the risk assessment procedure always considers individual pollutants, whereas in reality, several pollutants are usually present. Their total impact is therefore difficult to assess. In addition, human exposure from further sources can vary (consumption of different combinations of foodstuffs and different patterns of behaviour, such as with smoking).

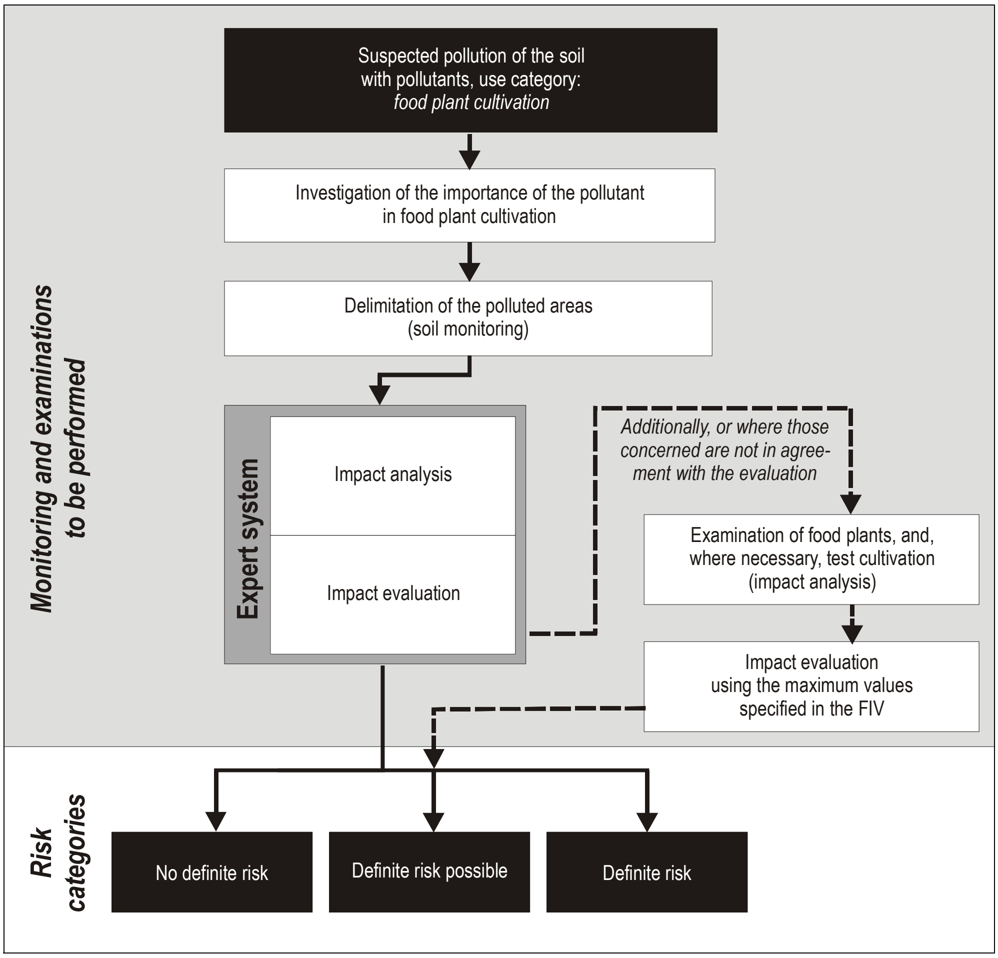
**Influence on procedure**

In risk assessment, the uncertainties must be kept as low as possible, and the entire procedure carefully laid down in advance. The principal requirements are:

- Documentation of the entire risk assessment procedure beginning with recording of the type of use and planning of sampling, through to determination of measures, and including the assumptions made;
- Performance by professionals who are able to gauge the significance of the uncertainties and avoid sources of error, both in field work (sampling, on-site assessment) and in impact analysis and assessment;
- Laboratory work: participation of the laboratory in inter-laboratory tests, and, where necessary, certification.

# 4 Risk assessment for food plant cultivation

Fig. 3: Risk assessment procedure in food plant cultivation.
[FIV: Foreign Substances and Additives Ordinance, OFSA; SR 817.021.23].




## 4.1 Expert system for food plant cultivation

### 4.1.1 Basics

**Expert system: fundamentals**

The expert system for food plant cultivation allows a simplified analysis of the risk involved in food plant cultivation. It is designed for pollutant concentrations lying between the trigger and clean-up values (trigger range), and is only applicable within this range.

The expert system takes the following parameters that affect the soil–to–plant pollutant transfer into account:

- Substance characteristics of the pollutant;
- Soil characteristics, namely the pH value, and content of organic substance and clay;
- Differing uptake behaviour of food plants.

Since for organic pollutants, plant exposure is often due in large measure to atmospheric deposition (BLUME 1992, BUWAL 1997b, DELSCHEN *et al.* 1999, SCHEFFER & SCHACHTSCHABEL 2002), and since insufficient data are available on soil–to–plant transfer, the expert system is restricted to inorganic pollutants. Among the organic pollutants, PAH are usually the most relevant to food plant cultivation (see recommendations in Annex 2E).

The maximum pollutant content given in the FIV (cf. Chap. 4.2.2) forms the basis for assessing the pollutant content of food plants.

### 4.1.2 Impact analysis

The expert system employs a point system for the assessment. In it, points are assigned to the individual parameters (impact, mobility, plant species and toxicity), and these added to give a total (risk score, G[3]). The risk increases with the number of points.

***Risk score G***

Calculation of risk score:

$$G = B + M + P + T \qquad \text{(N4.1)}$$

| | |
|---|---|
| *G* | *Risk score* |
| *B* | *Impact factor (between 0 and 5 points);* |
| *M* | *Mobility factor (between 0 and 6 points);* |
| *P* | *Plant species factor (between 0 and 2 points);* |
| *T* | *Correction factor for toxicity (between –1.5 and +1.5 points).* |

***Impact factor B***

The impact factor B is calculated as follows:

$$B = 5 \times \frac{C_{soil} - PW}{SW - PW} \qquad \text{(N4.2)}$$

| | |
|---|---|
| *B* | *Impact factor (points);* |
| $C_{soil}$ | *Soil pollutant impact on the soil ([mg/kg]; total content as specified in OIS);* |
| *PW* | *Trigger value for food plant cultivation as specified in OIS [mg/kg];* |
| *SW* | *Clean-up value for agriculture and horticulture, and/or home gardens and allotments, as specified in the OIS [mg/kg].* |

Where the pollutant impact is equal to the trigger value, B = 0. For the clean-up value, B = 5. Between these values, the impact factor increases linearly.

[3] **Note:** In this Manual the German abbreviations have been retained in all equations.

***Mobility factor M***

**Linkage force of the pollutant**

The mobility factor may be determined as shown in Fig. 4. As a first step, the relative linkage force of the pollutant in the soil is determined based on the soil characteristics pH, content of organic substance and clay. For this, the relevant data from lists A, B and C are added. Finally, the mobility factor is determined from the relative linkage force.

Fig. 4: Determination of the mobility factor. Lists A–C were prepared from data taken from the DVWK (1988), supplemented by data on fluorine from KELLER & DESAULES (2001) and SAEFL (1997c). According to SCHEFFER & SCHACHTSCHABEL (2002; p. 369), the mobility of Tl is roughly comparable to that of Zn, and that of As to that of Cr.

**A**

| *Pollutant* | *Relative linkage force at pH values (CaCl2) of* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *2.5* | *3.0* | *3.5* | *4.0* | *4.5* | *5.0* | *5.5* | *6.0* | *6.5* | *7.0* | *7.5* |
| *Cd* | 0 | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 5 |
| *Ni* | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 5 |
| *Co* | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 5 |
| *Zn* | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 5 |
| *Cu* | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 5 | 5 | 4 | 3 |
| *Cr* | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 5 | 5 | 5 | 5 |
| *Pb* | 1 | 2 | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 4 |
| *Hg* | 1 | 2 | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| *F* | 1 | 2 | 3 | 4 | 5 | 5 | 5 | 5 | 4 | 3 | 2 |

**B**

| *Pollutant* | *Relative linkage force at humus contents of* | | | |
|---|---|---|---|---|
| | *<2%* | *2-8%* | *8-15%* | *>15%* |
| *Cd* | 0 | 0 | 1 | 1 |
| *Ni* | 0 | 0 | 1 | 1 |
| *Co* | 0 | 0 | 0 | 1 |
| *Zn* | 0 | 0 | 0 | 0 |
| *Cu* | 0 | 1 | 1 | 2 |
| *Cr* | 0 | 1 | 1 | 2 |
| *Pb* | 0 | 1 | 1 | 2 |
| *Hg* | 0 | 1 | 1 | 2 |
| *F* | 0 | 1 | 1 | 2 |

**C**

| *Pollutant* | *Relative linkage force at clay contents of* | | |
|---|---|---|---|
| | *<25%* | *25-45%* | *>45%* |
| *Cd* | 0 | 0 | 0 |
| *Ni* | 0 | 0 | 0 |
| *Co* | 0 | 0 | 0 |
| *Zn* | 0 | 0 | 1 |
| *Cu* | 0 | 0 | 1 |
| *Cr* | 0 | 1 | 1 |
| *Pb* | 0 | 1 | 1 |
| *Hg* | 0 | 1 | 1 |
| *F* | n.a. | n.a. | n.a. |

For fluorine, no values (n.a.) are given by Keller and Desaules (2001) or by SAEFL (1997). For the expert system, the value 0 should be used.

**Sum of the relative linkage forces = relevant values of A+B+C**

| Sum of the relative linkage forces | 0 | 1 | 2 | 3 | 4 | 5 | >5 |
|---|---|---|---|---|---|---|---|
| **Mobility factor M** | **6** | **5** | **4** | **3** | **2** | **1** | **0** |

***Plant species factor P***

**Pollutant uptake by plants**

The plant species factors for a range of crops are shown in Tab. 6. Where no data on the required plant species are contained in the table, and if no data are available from other sources, an average pollutant uptake should be assumed (factor P = 1). In this case, the effect of assuming a high uptake on the result of the risk assessment should be ascertained.

Tab. 6: Plant species factors for crops with inorganic pollutants.

| Food plant | As | Cd | Co | Cr | Cu | Hg | Ni | Pb | Tl | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cereals** | | | | | | | | | | |
| barley (grain) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| oats (grain) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| maize (grain) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| rye (grain) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| wheat (grain) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **Vegetables** | | | | | | | | | | |
| *Root vegetables and tubers* | | | | | | | | | | |
| carrots | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| potatoes | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| celeriac | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| kohlrabi | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| radish | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| little radish | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| beetroot | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| scorzonera (black salsify) | – | 1 | – | – | – | – | – | 1 | 1 | – |
| *Onions and leeks* | | | | | | | | | | |
| leeks | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| onions | – | 0 | – | – | – | – | – | 1 | 0 | – |
| *Fruit vegetables* | | | | | | | | | | |
| aubergine | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| marrow | – | 0 | – | – | – | – | – | 0 | 0 | – |
| pumpkin | – | 0 | – | – | – | – | – | – | 0 | – |
| pepper (green/red/yellow) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| tomato | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| courgette (zucchini) | – | 0 | – | – | – | – | – | 0 | 0 | – |
| sweet corn | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Leaf vegetables* | | | | | | | | | | |
| cauliflower | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| broccoli | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| watercress | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Chinese cabbage | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| endive | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| corn salad (lamb’s lettuce) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| garden cress | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| curly kale | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| lettuce | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| lollo rosso (red lettuce) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| chard (silver beet) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Brussels sprouts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| red cabbage | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| spinach | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| white cabbage | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| savoy cabbage | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Stalk vegetables* | | | | | | | | | | |
| celery | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| *Pulses and legumes* | | | | | | | | | | |
| beans | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| peas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| rape | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| **Fruit** | | | | | | | | | | |
| berries (in general) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| pome fruit (in general) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| stone fruit (in general) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

0 = low uptake  1 = average uptake  2 = high uptake  – = not available

Data taken from BLUME (1992), IPE (1994), WENK *et al.* (1997), DELSCHEN & KÖNIG (1998). Where the data cited in the above literature differ, the highest value is given. For fluorine (F), no adequate data are available.

***Correction factor T (for toxicity)***
The risk associated with a substance depends not only on its uptake by plants, but also on its toxicity to humans. The correction factor T (for toxicity) was therefore introduced to create a relationship between the pollutant quantity taken up by plants and the maximum substance content given in the FIV (cf. Chap. 4.2.2). The maximum content is a measure of toxicity. However, the FIV stipulates maximum values only for the heavy metals Cd, Pb and Tl for food plants; at international level, values have till now only been specified for Cd and Pb (BERG & LICHT 2002). The correction factors T for Cd, Pd and Tl were determined by statistical methods based on a large number of measured pollutant concentrations in the soil and plants (cf. Annex 9A).

In the OIS, the clean-up values for Cu and Zn were laid down with a view to protecting plants (from loss of productivity), and not to protecting humans (SAEFL 1997a; also see Annexes 2C and 2D). The correction factors T for these two substances were therefore reduced. For all other substances for which the FIV does not specify a maximum content, the correction factors were set to T = 0, signifying ‹not ascertainable›.

Tab. 7: Correction factors T for inorganic pollutants (food plant cultivation).

| Element | As | Cd | Co | Cr | Cu | F | Hg | Ni | Pb | Tl | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Correction factor T | 0 | **0.5** | 0 | 0 | –1.5 | 0 | 0 | 0 | **0** | **0** | –1.5 |

Figures in bold type = correction factors T determined by statistical methods.

### 4.1.3 Impact evaluation

**Risk categories**

The risk score determined from *Equation (N4.1)* is assigned to the risk categories using Tab. 8.

Tab. 8: Risk categories in the expert system for food plant cultivation.

| Risk score G = B + M + P + T | <3 | 3–<5 | ≥5 |
|---|---|---|---|
| Risk category for Cd, Pb, Tl * | No definite risk | Definite risk possible | Definite risk |
| Risk categories for As, Co, Cr, Cu, F, Hg, Ni, Zn | No definite risk | Definite risk possible | Definite risk possible |

* The uncertainties in risk assessment must be assumed greater than for Cd and Pb, since the uptake of Tl by plants is less well established.

The reason for having two different risk assessment categories here lies in the non–availability of data on maximum content for all of the inorganic pollutants except Cd, Pb and Tl (cf. Chap. 4.1.2, correction factor T and Annex 9). For the remaining heavy metals, the position of the boundary between the trigger and clean-up values above which a definite risk exists cannot be clearly established. The resulting risk score may be taken as a measure of the probability that a definite risk exists.

Examples of the use of the expert system in agriculture and horticulture are given in Annex 1A and for gardens in Annex 1D. As an aid in applying these methods, pre-programmed spreadsheets for the uses «agriculture and horticulture» and «home gardens» are available.[4]

## 4.2 Detailed risk assessment for food plant cultivation

### 4.2.1 Impact analysis

A detailed risk assessment may be carried out by examining food plants grown on the polluted plot. For this, at least two species of food plant must be analysed for pollutant content. Species that accumulate the pollutant to a different extent should be chosen (cf. Tab. 6).

**Test cultivation and sampling**

Should no representative selection of food plants be present on the plot concerned, a cultivation test can be performed. As a general rule, the higher the extent of pollution, the larger the area, and the higher the possible risk to humans or animals associated with the use concerned, the more essential it is to perform a cultivation test. Detailed information on cultivation tests and sampling is given in Annex 3.

**Analysis and reserve samples**

Several mixed samples should be taken for each plant species and one of these analysed. The remaining samples are set aside for later analysis should this be necessary. The plants are analysed in a form ready for cooking, i.e. the edible parts are washed or cleaned prior to analysis to ensure they are free of soil. Analysis is performed in accordance with foodstuffs legislation.

### 4.2.2 Impact evaluation

**Maximum content stipulated in the FIV**

The assessment of the pollutant content of food plants is based on the maximum content stipulated in the FIV for foodstuffs (cf. Tab. 9). The maximum content is specified for food plants for sale on the market, but it can also be applied to assess food plants not for sale:

- ***Tolerance values*** represent maximum concentrations of substances above which the foodstuff is rated as polluted or otherwise of inferior quality.
- ***Limit values*** are maximum concentrations above which the foodstuff is rated as unsuitable for human consumption.

---

[4] cf. excel format: http:\\www.environnement-suisse.ch→thèmes→sol→mise en œuvre de l'OSol→ manuel évaluation de la menace.

Tab. 9: Selected FIV maximum content relevant to the OIS (as of July 2004).

| Substance | FIV maximum content [mg/kg fresh weight] | Foodstuff | Classification of maximum content |
|---|---|---|---|
| Cd | 0.2 | leaf vegetables, celeriac, fresh kitchen herbs, wheat | limit value |
| Cd | 0.1 | other cereals, root vegetables and tubers, stalk vegetables | limit value |
| Cd | 0.05 | other vegetables, fruit | limit value |
| Pb | 0.3 | leaf vegetables, cabbage species | limit value |
| Pb | 0.2 | cereals, pulses, berries | limit value |
| Pb | 0.1 | other vegetables, other fruit | limit value |
| Tl | 0.1 | vegetables, berries, pome fruit, stone fruit | tolerance value |
| Benzo(a)pyrene (originating from environmental pollution) | 0.001 | vegetables, berries, pome fruit, stone fruit | tolerance value |
| Polychlorinated biphenyls | 0.1 | vegetable foodstuffs | limit value |

The above data is provided as a guide; final values must be taken from the current version of the FIV.

In general, the FIV provides only one of the two values (i.e. either a tolerance value or a limit value) for the pollutants relevant to risk assessment. Where not otherwise stated, the maximum content applies to the fresh weight of the well washed or cleaned edible parts of the foodstuff (i.e. excluding soil and dust). Vegetables are defined in Art. 188 of the *Ordinance relating to Foodstuffs and Articles of Daily Use of 1 March 1995 (LMV; SR 817.02)* as plants or parts of plants intended for human consumption.

Where the FIV specifies both a tolerance value and a limit value for a particular substance, the limit value must be used, since a risk to health need only be assumed for pollutant concentrations beyond this value. Where the FIV does not specify a maximum value for a substance, this can be taken in general from comparable legislation abroad, for example that applying in the EU (cf. Chap. 9, additional information on risk assessment). However, for inorganic pollutants in foodstuffs, only the limit values for Cd and Pb have been laid down in international legislation (cf. Chap. 4.1.2; correction factor T and Annex 9). Further information may be obtained from the cantonal chemical laboratories.

**Risk categories**

The assignment of a risk category is done as shown in Tab. 10. Where the maximum content specified in the FIV is exceeded, the category *«definite risk»* is applied. The category *«definite risk possible»* is assigned above a value exceeding the average between an uncontaminated food plant ($c_{uncontaminated}$) and the maximum (i.e. significantly raised concentration). The pollutant content of plants in uncontaminated areas is given in Tab. 11. Data on further pollutants and food plants can be obtained when necessary from the Swiss Office of Public Health (BAG), Division of Foodstuffs Toxicology.

The risk must be assessed for each plant species under examination and for each relevant pollutant. In determining measures, e.g. recommendations for use (cf. Chap. 8.2), it is useful to obtain data for plant species that accumulate the pollutant to different extents.

**Notes on risk as defined in foodstuffs legislation**

In soil legislation, a risk is always regarded as definite if it is actually realised at some point in time during the normal course of events, i.e. an impairment to health and the environment occurs.

In foodstuffs legislation, the term risk is applied in a similar way to the health field. Thus when a limit value is exceeded, the term risk can be applied (cf. Arts. 10 and 47 LMV). According to Art. 2 FIV, values exceeding the limit value indicate that the foodstuff in question is unsuitable for consumption.

However, where the tolerance values alone are exceeded, there is no risk to health. Therefore the term risk in this manual implies that it is not possible to produce a foodstuff of this category conforming to legislation on the soil in question.

Tab. 10: Risk categories for food plant cultivation.

| Impact | Risk category |
|---|---|
| $c_{measured} < \frac{c_{uncontaminated} + c_{maximum\ value}}{2}$ | Risk category |
| $\frac{c_{uncontaminated} + c_{maximum\ value}}{2} \leq c_{measured} < c_{maximum\ value}$ | No risk |
| $c_{measured} \geq c_{maximum\ value}$ | Definite risk |

c = concentration referred to fresh weight. Data on $C_{uncontaminated}$ are given in Tab. 11.

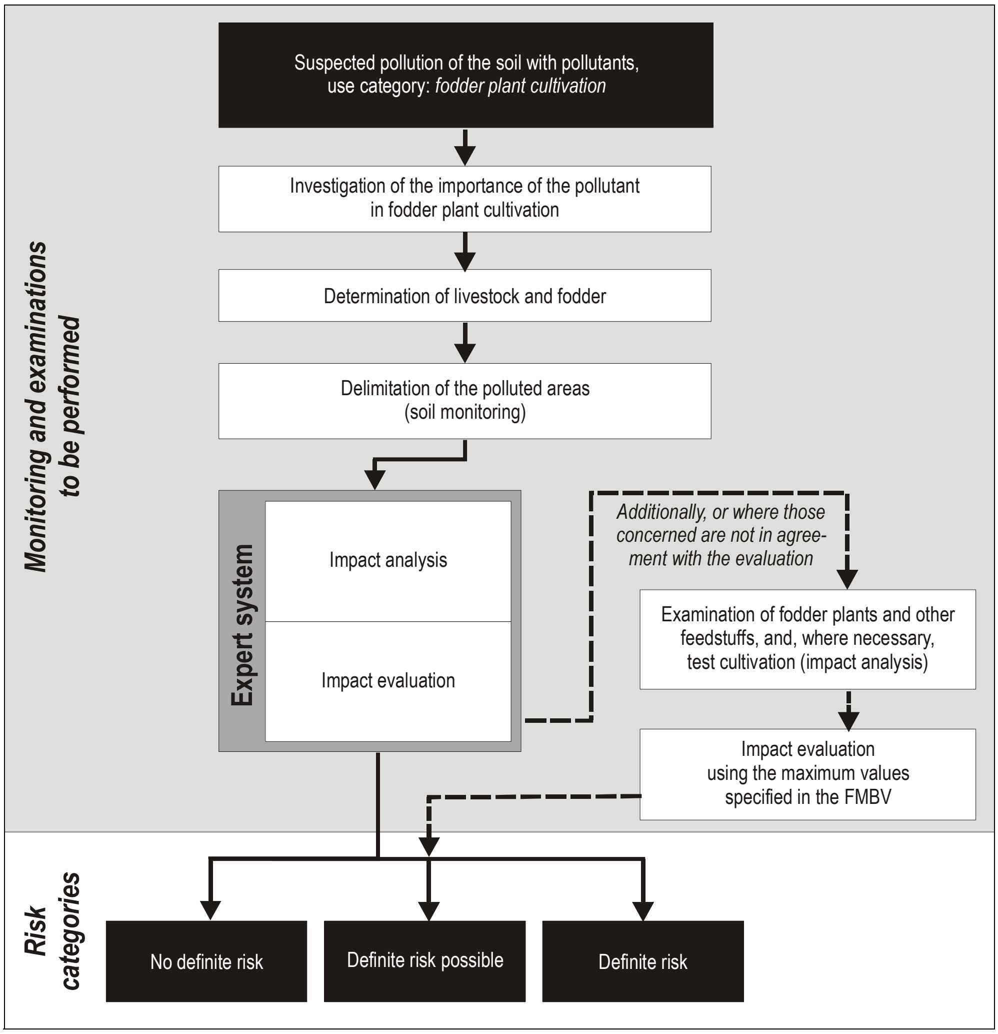
Tab. 11: Substance content of uncontaminated food plants (mg/kg fresh weight).

| Food plant | As | Cd | Co | Cr | Cu | F | Hg | Mo | Ni | Pb | Sb | Se | Sn | Tl | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cereals* | | | | | | | | | | | | | | | |
| barley (grain) | 0.07 | 0.04 | 0.05 | 0.26 | 4.4 | 2.6 | 0.02 | 0.5 | 0.4 | 0.08 | 0.02 | 0.04 | 0.2 | 0.04 | 35 |
| oats (grain) | 0.10 | 0.05 | 0.08 | 0.39 | 6.5 | 2.6 | 0.03 | 0.8 | 0.7 | 0.16 | 0.03 | 0.05 | 0.3 | 0.05 | 52 |
| rye (grain) | 0.03 | 0.03 | 0.03 | 0.13 | 2.2 | 2.6 | 0.01 | 0.3 | 0.2 | 0.08 | 0.01 | 0.02 | 0.1 | 0.02 | 17 |
| wheat (grain) | 0.10 | 0.05 | 0.08 | 0.39 | 6.5 | 2.6 | 0.03 | 0.8 | 0.7 | 0.16 | 0.03 | 0.05 | 0.3 | 0.05 | 52 |
| *Root vegetables and tubers* | | | | | | | | | | | | | | | |
| carrots | 0.01 | 0.01 | 0.010 | 0.05 | 0.9 | 0.4 | 0.004 | 0.1 | 0.09 | 0.02 | 0.004 | 0.007 | 0.04 | 0.007 | 7 |
| potatoes | 0.02 | 0.009 | 0.010 | 0.07 | 1.1 | 0.7 | 0.004 | 0.1 | 0.1 | 0.03 | 0.004 | 0.009 | 0.04 | 0.009 | 9 |
| celeriac | 0.01 | 0.007 | 0.010 | 0.05 | 0.8 | 0.3 | 0.003 | 0.1 | 0.08 | 0.02 | 0.003 | 0.007 | 0.03 | 0.007 | 7 |
| kohlrabi | 0.01 | 0.003 | 0.005 | 0.02 | 0.4 | 0.2 | 0.002 | 0.05 | 0.04 | 0.01 | 0.002 | 0.003 | 0.02 | 0.003 | 3 |
| radish | 0.01 | 0.003 | 0.004 | 0.02 | 0.4 | 0.2 | 0.001 | 0.04 | 0.04 | 0.01 | 0.001 | 0.003 | 0.01 | 0.003 | 3 |
| little radish | 0.01 | 0.002 | 0.004 | 0.02 | 0.3 | 0.2 | 0.001 | 0.04 | 0.03 | 0.01 | 0.001 | 0.002 | 0.01 | 0.002 | 3 |
| beetroot | 0.01 | 0.004 | 0.007 | 0.03 | 0.6 | 0.3 | 0.002 | 0.07 | 0.06 | 0.01 | 0.002 | 0.004 | 0.02 | 0.004 | 4 |
| scorzonera (black salsify) | 0.01 | 0.008 | 0.006 | 0.03 | 0.5 | 0.6 | 0.002 | 0.06 | 0.05 | 0.03 | 0.002 | 0.004 | 0.02 | 0.008 | 4 |
| *Onions and leeks* | | | | | | | | | | | | | | | |
| leeks | 0.01 | 0.007 | 0.010 | 0.05 | 0.8 | 0.3 | 0.003 | 0.1 | 0.08 | 0.02 | 0.003 | 0.007 | 0.03 | 0.007 | 7 |
| onions | 0.01 | 0.002 | 0.004 | 0.02 | 0.3 | 0.4 | 0.001 | 0.04 | 0.03 | 0.01 | 0.001 | 0.002 | 0.01 | 0.002 | 2 |
| *Fruit vegetables* | | | | | | | | | | | | | | | |
| aubergine | 0.01 | 0.001 | 0.002 | 0.02 | 0.2 | 0.2 | 0.001 | 0.04 | 0.02 | 0.01 | 0.001 | 0.001 | 0.01 | 0.001 | 1 |
| marrow | 0.01 | 0.001 | 0.001 | 0.01 | 0.1 | 0.1 | 0.001 | 0.01 | 0.01 | 0.01 | 0.001 | 0.001 | 0.01 | 0.001 | 1 |
| pumpkin | 0.01 | 0.002 | 0.003 | 0.01 | 0.2 | 0.3 | 0.001 | 0.03 | 0.02 | 0.01 | 0.001 | 0.002 | 0.01 | 0.002 | 2 |
| pepper (green/red/yellow) | 0.01 | 0.002 | 0.003 | 0.01 | 0.2 | 0.3 | 0.001 | 0.03 | 0.02 | 0.01 | 0.001 | 0.002 | 0.01 | 0.002 | 2 |
| tomato | 0.01 | 0.001 | 0.002 | 0.01 | 0.2 | 0.2 | 0.001 | 0.02 | 0.02 | 0.01 | 0.001 | 0.001 | 0.01 | 0.001 | 2 |
| courgette (zucchini) | 0.01 | 0.001 | 0.002 | 0.01 | 0.1 | 0.2 | 0.001 | 0.02 | 0.01 | 0.01 | 0.001 | 0.001 | 0.01 | 0.001 | 1 |
| sweet corn | 0.01 | 0.005 | 0.008 | 0.04 | 0.6 | 0.8 | 0.003 | 0.08 | 0.06 | 0.02 | 0.003 | 0.005 | 0.03 | 0.005 | 5 |
| *Leaf vegetables* | | | | | | | | | | | | | | | |
| cauliflower | 0.01 | 0.003 | 0.005 | 0.02 | 0.4 | 0.2 | 0.002 | 0.05 | 0.04 | 0.01 | 0.002 | 0.003 | 0.02 | 0.003 | 3 |
| broccoli | 0.01 | 0.004 | 0.003 | 0.02 | 0.3 | 0.3 | 0.001 | 0.03 | 0.03 | 0.01 | 0.001 | 0.002 | 0.01 | 0.004 | 2 |
| watercress | 0.01 | 0.004 | 0.006 | 0.03 | 0.5 | 0.2 | 0.002 | 0.06 | 0.05 | 0.01 | 0.002 | 0.004 | 0.02 | 0.004 | 4 |
| Chinese cabbage | 0.01 | 0.002 | 0.003 | 0.02 | 0.3 | 0.2 | 0.001 | 0.03 | 0.03 | 0.01 | 0.001 | 0.002 | 0.01 | 0.002 | 2 |
| endive | 0.01 | 0.004 | 0.005 | 0.03 | 0.5 | 0.2 | 0.002 | 0.05 | 0.05 | 0.01 | 0.002 | 0.004 | 0.02 | 0.004 | 4 |
| corn salad (lamb's lettuce) | 0.01 | 0.004 | 0.006 | 0.03 | 0.5 | 0.2 | 0.002 | 0.06 | 0.05 | 0.01 | 0.002 | 0.004 | 0.02 | 0.004 | 4 |
| garden cress | 0.02 | 0.008 | 0.010 | 0.06 | 1.0 | 0.4 | 0.004 | 0.2 | 0.1 | 0.02 | 0.004 | 0.008 | 0.04 | 0.008 | 8 |
| curly kale | 0.01 | 0.006 | 0.008 | 0.04 | 0.7 | 0.4 | 0.003 | 0.08 | 0.07 | 0.02 | 0.003 | 0.006 | 0.03 | 0.008 | 6 |
| lettuce | 0.01 | 0.003 | 0.005 | 0.02 | 0.4 | 0.2 | 0.002 | 0.05 | 0.04 | 0.01 | 0.002 | 0.003 | 0.02 | 0.003 | 3 |
| lollo rosso (red lettuce) | 0.01 | 0.006 | 0.009 | 0.05 | 0.8 | 0.3 | 0.003 | 0.09 | 0.08 | 0.02 | 0.003 | 0.006 | 0.03 | 0.006 | 6 |
| chard (silver beet) | 0.01 | 0.005 | 0.007 | 0.04 | 0.6 | 0.2 | 0.002 | 0.07 | 0.06 | 0.01 | 0.002 | 0.005 | 0.02 | 0.005 | 5 |
| Brussels sprouts | 0.01 | 0.003 | 0.005 | 0.02 | 0.4 | 0.5 | 0.002 | 0.05 | 0.04 | 0.02 | 0.002 | 0.003 | 0.02 | 0.003 | 3 |
| red cabbage | 0.01 | 0.003 | 0.005 | 0.02 | 0.4 | 0.2 | 0.002 | 0.05 | 0.04 | 0.01 | 0.002 | 0.003 | 0.02 | 0.003 | 3 |
| spinach | 0.01 | 0.005 | 0.007 | 0.04 | 0.6 | 0.2 | 0.002 | 0.07 | 0.06 | 0.01 | 0.002 | 0.005 | 0.02 | 0.005 | 5 |
| white cabbage | 0.01 | 0.003 | 0.005 | 0.02 | 0.4 | 0.2 | 0.002 | 0.05 | 0.04 | 0.01 | 0.002 | 0.003 | 0.02 | 0.003 | 3 |
| savoy cabbage | 0.01 | 0.004 | 0.006 | 0.03 | 0.5 | 0.3 | 0.002 | 0.06 | 0.05 | 0.01 | 0.002 | 0.004 | 0.02 | 0.004 | 4 |
| *Stalk vegetables* | | | | | | | | | | | | | | | |
| celery | 0.01 | 0.004 | 0.002 | 0.01 | 0.2 | 0.2 | 0.001 | 0.02 | 0.02 | 0.01 | 0.001 | 0.001 | 0.01 | 0.003 | 1 |
| *Pulses and legumes* | | | | | | | | | | | | | | | |
| beans | 0.01 | 0.002 | 0.003 | 0.02 | 0.3 | 0.3 | 0.001 | 0.03 | 0.03 | 0.01 | 0.001 | 0.002 | 0.01 | 0.002 | 2 |
| peas | 0.01 | 0.005 | 0.007 | 0.04 | 0.6 | 0.7 | 0.002 | 0.07 | 0.06 | 0.01 | 0.002 | 0.005 | 0.02 | 0.005 | 5 |
| rape | 0.01 | 0.002 | 0.003 | 0.02 | 0.3 | 0.3 | 0.001 | 0.03 | 0.03 | 0.01 | 0.001 | 0.002 | 0.01 | 0.006 | 2 |
| *Fruit* | | | | | | | | | | | | | | | |
| berries (in general) | 0.01 | 0.003 | 0.004 | 0.02 | 0.3 | 0.4 | 0.001 | 0.04 | 0.03 | 0.01 | 0.001 | 0.003 | 0.01 | 0.003 | 3 |
| pome fruit (in general) | 0.01 | 0.003 | 0.005 | 0.02 | 0.4 | 0.5 | 0.002 | 0.05 | 0.04 | 0.01 | 0.002 | 0.003 | 0.02 | 0.003 | 3 |
| stone fruit (in general) | 0.01 | 0.003 | 0.005 | 0.02 | 0.4 | 0.5 | 0.002 | 0.05 | 0.04 | 0.01 | 0.002 | 0.003 | 0.02 | 0.003 | 3 |

Data taken from IPE (1994), BLUME (1992), WENK *et al.* (1997), DELSCHEN & KÖNIG (1998), GISI *et al.* (1990). Conversion from dry matter to fresh weight performed using the water content of crops in SAEFL (1997a, p. 95 ff.).

# 5 Risk assessment for fodder plant cultivation

Fig. 5: Procedure for risk assessment for fodder plant cultivation.
[FMBV: Livestock Feedstuff Book Ordinance, LFBO; SR 916.307.1].




## 5.1 Expert system for fodder plant cultivation

### 5.1.1 Fundamentals

The expert system for fodder plant cultivation permits a simplified analysis of the risk in this context. The system is designed for pollutant concentrations lying between the trigger and clean-up values (trigger range), and must only be used within this range.

The expert system takes the following factors, which influence the pollutant transfer soil (→ plant) → livestock, into account:

- Percentage of direct oral ingestion and/or soiling of fodder;
- Specific substance properties of the pollutant;

- Soil characteristics, namely pH value and content of organic substance or clay;
- Uptake behaviour of different fodder plants;
- Sensitivity of different livestock.

**FMBV maximum content**

The pollutant content of fodder plants is assessed based on the maximum content stipulated in the FMBV (cf. Tab. 12 and Chap. 5.2.2). In cases where no maximum content is specified in the FMBV, the critical values of elements in animal feedstuffs according to BLUME (1992) may be used as a guide. The same applies to individual feedstuffs where the FMBV only specifies the maximum content of an element in the entire feed.

Tab. 12: Maximum content according to FMBV for selected elements [as of July 2004] and critical values for animal feedstuffs (cf. BLUME 1992).

| Substance | FMBV maximum content [mg/kg at 88 % dry matter] | Critical values for animal feedstuff according to BLUME (1992) [mg/kg dry matter] |
|---|---|---|
| As | 2 | – |
| Cd | 1 | – |
| Cr | – | 50–3000 |
| Co | 2* | 10–50 |
| Cu | • Cattle (consumption of roughage): 35*<br>• Sheep: 15* | 30–100 |
| F | 150 | – |
| Hg | 0.1 | – |
| Mo | 2.5* | 10–58 |
| Ni | – | 50–60 |
| Pb | 40 (green fodder) | – |
| Se | 0.5* | 4–5 |
| Tl | – | 1–5 |
| Zn | 150* | 300–1000 |
| Sum PCDD/F [ng TEQ according to WHO] | 0.75 | – |

* Maximum value for the entire feed. TEQ = toxicity equivalent, cf. Annex 2G. Where values are quoted in the FMBV, those for the feedstuffs most likely to occur were used. Users should refer to the current version of the FMBV to obtain the latest values. Where the critical values according to BLUME 1992 are used as a guide, the lowest value in the range given should normally be applied.

Since the impact of organic pollutants on plants is to a large extent the result of atmospheric deposition (BLUME 1992, SAEFL 1997b, DELSCHEN *et al.* 1999, SCHEFFER & SCHACHTSCHABEL 2002) and insufficient data is available on the transfer from the soil to plants, the expert system is restricted entirely to inorganic pollutants. However, the risk arising from direct oral ingestion or crop soiling can also be calculated for organic pollutants in cases where the FMBV stipulates a maximum content for the substance concerned. Ingestion from these sources is independent of soil-to-plant transfer and in most cases will represent the greater part of the pollutant intake of livestock.

### 5.1.2 Impact analysis

The expert system performs the analysis based on a point system. In this, points are assigned to the individual parameters (soil contribution, impact, mobility, plant species and toxicity), and these added to provide a global number *(risk score, G)*. The risk increases with the number of points.

***Risk score G***

Calculation of risk score:

$$G = E + B + M + P + T \qquad \text{(F5.1)}$$

| | |
|---|---|
| $G$ | *Risk score;* |
| $E$ | *Soil contribution factor;* |
| $B$ | *Impact factor for soil–to–plant transfer (root uptake; between 0 and 8 points);* |
| $M$ | *Mobility factor (between 0 and 6 points);* |
| $P$ | *Plant species factor (between 0 and 2 points);* |
| $T$ | *Correction factor (between 0 and 4 points).* |

The soil contribution factor E accounts for the impact from direct oral soil ingestion and/or crop soiling (root uptake) caused by the feedstuff concerned. The factors B, M, P and T are related to the soil–to–plant transfer (root uptake).

For the elements Cd, Cu and Zn, the contribution from root uptake in comparison to direct oral ingestion or crop soiling is relevant, or may indeed form the principal part (cf. Annex 9B).

For the elements As, Pb, Cr, Ni and Hg, however, the contribution from root uptake is in most cases negligible. Thus for risk assessment, only the soil contribution factor E must be calculated. In this case, the other factors are set to 0.

For other elements (e.g. F, Co, Mo, Se), the magnitude of the soil–to–plant transfer is not well established. For these, the risk score is calculated using a simplified procedure (cf. Equation F5.4).

The individual factors are determined as follows:

***Soil contribution factor E***

Calculation of the soil contribution factor E:

$$E = 8 \times \frac{C_{soil}}{HG} \times \frac{d}{100} \qquad \text{(F5.2)}$$

| | |
|---|---|
| $E$ | *Soil contribution factor (points);* |
| $C_{Soil}$ | *Pollutant impact on soil ([mg/kg]; total content according to OIS);* |
| $HG$ | *Maximum pollutant content of feedstuff (normally value for individual feedstuff) for the livestock concerned according to FMBV ([mg/kg]; cf. Tab. 12);* |
| $d$ | *Contribution from direct oral soil ingestion/crop soiling for the feedstuff concerned in percent of total consumption (cf. Tab. 13).* |

Where the FMBV specifies a maximum content both for complete feed and for individual feedstuffs, the value for individual feedstuffs should normally be used. The reason for this is that fodder from a polluted plot normally represents only a part of the diet, so that the requirements for an individual feedstuff are applied.

For the expert system, the factor d (soil ingestion, cf. Tab. 13) should be set equal to the average value under dry soil conditions, since this is the normal case. In the FMBV, the maximum content applies to long-term ingestion of a substance, and a short-term increase in ingestion under wet soil conditions is not an acute problem. However, the risk should also be calculated under wet soil conditions to provide guidance to the farmer at harvest time and for livestock grazing.

Tab. 13: Contribution of soil ingestion of livestock (d) either directly or through crop soiling.*

| **Crop** | **Soil ingestion (d) direct or through contamination with soil particles** [in % of consumption; dm] | | | | **Maximum percentage of feed plants in total feed over a longer period** [%] | |
|---|---|---|---|---|---|---|
| | Cattle | | Sheep | | Cattle | Pig |
| | Grazing/harvest conditions | | | | | |
| | Dry soil | Wet soil | Dry soil | Wet soil | | |
| Direct consumption (grazing, cut meadow) | 0–5 | 5–10 | 10–15 | 20–30 | 100 | – |
| cut grass/grass silage | 0–5 | 10–15 | 0–5 | 10–15 | – | – |
| hay | 0–3 | 5–10 | 0–3 | 5–10 | 100 | – |
| | **Crop contamination with soil particles: contribution soil (d)** [% harvest; dm] | | | | | |
| Feed grain (excl. field beans): | 0 | | | | 40 | 80 |
| • barley | 0 | | | | – | 40 |
| • oats | 0 | | | | – | – |
| • wheat | 0 | | | | – | 40 |
| • maize (grain) | 0 | | | | – | 30 |
| field bean<br>field pea | slight (approx. 0–2) | | | | 15 | 20 |
| fodder beet | 10 | | | | 30 | 40 |
| potato | slight (approx. 0–2) | | | | 20 | 30 |
| maize (whole plant) | slight (approx. 0–2) | | | | 80 | 15 |

* Prepared from data of the Livestock Research Institute in Posieux *(Agroscope ALP Posieux)*. The figures refer to the percentage actually ingested by livestock. In certain cases, the percentage content in feedstuffs can be higher. Here, however, feedstuffs with exceptionally high soiling are often not consumed by livestock, but left untouched. Data on soil ingestion by sheep are given by ABRAHAMS & STEIGMAJER (2003). The two right-hand columns are intended for detailed risk assessment when applying threshold values (cf. Annex 4).

***Impact factor B for soil–to–plant transfer (root uptake)***
The impact factor B is calculated as follows:

$$B = 8 \times \frac{C_{soil} - PW}{SW - PW} \qquad \text{(F5.3)}$$

| | |
|---|---|
| *B* | *Impact factor for soil–to–plant transfer (root uptake);* |
| $C_{Soil}$ | *Pollutant impact on soil ([mg/kg]; total content according to OIS);* |
| *PW* | *Trigger value for fodder plant cultivation as specified in OIS (mg/kg);* |
| *SW* | *Clean-up value for agriculture and horticulture as specified in OIS (mg/kg).* |

In most cases, the exposure to livestock stems primarily from direct oral soil ingestion or crop soiling. When the soil contribution factor E is ≥8, this fraction alone is sufficient to cause fodder from the polluted plot to have a higher pollutant content than permitted by the FMBV. Assignment of the category *«definite risk»* is then unavoidable (cf. impact evaluation).

If the pollutant impact corresponds to the trigger value, B = 0. If it corresponds to the clean-up value, B = 8. Between these two points, the impact factor increases linearly.

***Mobility factor M***
The mobility factor is determined in the same way as for the expert system for food plant cultivation (cf. Chap. 4.1.2).

***Plant species factor P***

**Pollutant uptake by plants**

The plant species factors for a range of fodder plants are shown in Tab. 14. Where the required plant species is not shown in the table, and if data are not available from other sources, an average value for the pollutant uptake should be assumed. In this case, the effect of a high uptake on the result of the risk assessment should be ascertained.

Tab. 14: Plant species factors for fodder plants and inorganic pollutants.

| Fodder plant | As | Cd | Co | Cr | Cu | Hg | Mo | Ni | Pb | Sb | Se | Sn | Tl | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| barley (grain) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| grass (in general) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| oats (grain) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| potato | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| lucerne | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| maize (grain) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| rye (grain) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| wheat (grain) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| sugar beet (leaves) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

0 = low uptake 1 = average uptake 2 = high uptake
Data taken from BLUME (1992), IPE (1994), WENK *et al.* (1997), DELSCHEN & KÖNIG (1998). Where the data in the literature cited differ, the highest value is shown.

***Correction factor T***

The risk arising from a substance depends not only on its transfer to the plant, but also on its toxicity to livestock. The correction factor T was introduced to create a relationship between the pollutant quantity taken up by plants and the maximum content stipulated in the FMBV (cf. Chap. 4.2.2). The maximum content is a measure of the toxicity of a substance. For Cd, Cu and Zn, the correction factor T was determined from a large number of measured pollutant concentrations in the soil and plants on the basis of statistical procedures (cf. Annex 9B).

Tab. 15: Correction factors T for inorganic pollutants (fodder plant cultivation).

| Element | Cd | Cu | Zn |
|---|---|---|---|
| Korrekturfaktor T* | 3 | 0 | 1 |

* Correction factors T determined using statistical methods.

***Simplified impact analysis for other pollutants***

**Simplified procedure for F, Co, Mo, Se**

Where the FMBV specifies maximum values, but the soil–to–plant transfer is less well established (e.g. F, Co, Mo, Se), the risk score G may be calculated using the following equation:

$$G = E + \left[ 8 \times \frac{C_{soil}}{HG} \times TK \right] \qquad \text{(F5.4)}$$

| | |
|---|---|
| *G* | *Risk score;* |
| *E* | *Soil contribution factor (points), calculated according to Equation (F5.2);* |
| $C_{Soil}$ | *Pollutant exposure of the soil ([mg/kg]; total content as specified in OIS);* |
| *HG* | *Maximum content of feedstuff as specified in FMBV (normally the value for individual feedstuff) for the livestock concerned ([mg/kg]; cf. Tab. 12);* |
| *TK* | *Soil–to–plant transfer coefficient (see examples in Tab. 16).* |

The soil–to–plant transfer coefficient can only be given as a broad range (cf. Tab. 16). To obtain a rough initial estimate of the exposure, an average value for the transfer coefficient should be set in Equation (F5.4). In addition, the effect of a higher transfer coefficient should be examined.

Tab. 16: Soil-to-plant transfer coefficients for F, Co, Mo and Se.

| Element | F | Co | Mo | Se |
|---|---|---|---|---|
| Soil–to–plant transfer coefficient | 0.01–0.1 | 0.01–0.1 | 0.1–10 | 0.1–10 |

Data according to BLUME (1992).

### 5.1.3 Impact evaluation

**Risk categories**

The risk score determined from Equation (F5.1) or (F5.4) is assigned to risk categories as shown in Tab. 17.

Tab. 17: Risk score in the expert system for fodder plant cultivation.

| Risk score G = E + B + M + P + T | <5 | 5–<8 | ≥8 |
|---|---|---|---|
| Risk categories for:<br>As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, Co*, F*, Mo*, Se* | No risk | Definite risk possible | Definite risk |

* The uncertainty in risk assessment should be assumed greater than for other elements, since the uptake of these elements by plants is less well established and/or their behaviour in the soil is extremely complex (particularly for Mo and Se, which undergo several oxidation phases).

An example of the application of the expert system is given in Annex 1B. A simplified method for the use category fodder plant cultivation is available as a spreadsheet.[5]

## 5.2 Detailed risk assessment for fodder plant cultivation

For detailed studies involving fodder plant cultivation, it is always recommended to consult an agricultural specialist.

### 5.2.1 Impact analysis

**Examination of fodder plants**

The pollutant content of fodder plants originating from polluted plots must be determined. For cut meadows, pastures and cut pastures, the pollutant content of the fodder plants produced can be analysed. On arable plots used for fodder production, crop rotation must be considered. In such cases, a cultivation test with fodder plants grown on the plot concerned may prove necessary (cf. Annex 3).

For fodder plants for sale on the market, sampling must accord with the provisions of FMBV Annex 9. This procedure is also recommended in other cases.

The following methods are applied for analysing fodder plants:

- Reference methods of the agricultural research institutes (AGROSCOPE FAL 1995);
- Book of methods for the examination for soil plants and lysimeter percolates (AGROSCOPE FAL 1998).

5 cf. excel format: http:\\www.environnement-suisse.ch→thèmes→sol→mise en œuvre de l'OSol→ manuel évaluation de la menace.

***Calculations of the impact of individual pollutants***

**Impact from individual fodder plants**

The exposure of the livestock concerned is determined based on the pollutant content of the soil and fodder plants. For this, the exposure paths for fodder plant cultivation (cf. Tab. 2, Chap. 3.3.2) must be combined using the following formula (simplified according to SAEFL 1997a; 1998):

$$B_i = d_i * C_{soil} + C_{fodder\ plant} \quad \text{(F5.5)}$$

| | |
|---|---|
| $B_i$ | *Impact on livestock from fodder plant i [mg/kg dm];* |
| $d_i$ | *Fraction of direct oral soil ingestion/soiling of the fodder plant i (cf. Tab. 13);* |
| $C_{soil}$ | *Pollutant impact on the soil ([mg/kg]; total content as specified in OIS) Normal sampling depth: 0–5 cm. For soiling of deep-rooted plants (e.g. beet crops): 0–20 cm;* |
| $C_{fodder\ plant}$ | *Pollutant content of fodder plant [mg/kg dm].* |

This calculation is performed for each livestock category concerned and for each individual pollutant.

***Comments on the influence of the exposure paths***

**Root uptake**

Where the livestock concerned is mainly subject to the exposure path root uptake (that is, via the fodder plants themselves), i.e. when $d_i$ in Equation (F5.5) is small, the risk is influenced by the soil characteristics. In this case, for inorganic pollutants, increased risk is indicated particularly by a low pH value and/or high soluble pollutant content. Where the lime content or the cation exchange capacity is high, the potential future risk is lower owing to the good buffer or sorption characteristics of the soil.

**Direct oral soil ingestion**

Where the livestock concerned is exposed mainly through direct oral soil ingestion, i.e. when $d_i$ in Equation (F5.5) is large, the risk mainly depends on the total content as given in OIS.

### 5.2.2 Impact evaluation

**Ordinances on feedstuffs**

For animal feedstuffs, the FMV and the FMBV apply. Annex 2 FMBV specifies maximum contents for approved additives in feedstuffs (e.g. Co, Cu, Mo, Se, Zn), which in high concentrations can be toxic to livestock.

Annex 10 FMBV specifies maximum contents for undesired substances in feedstuffs, and applies to feedstuffs for sale on the market. However, these can also be applied to the assessment of feedstuffs not for sale on the market.

**Risk categories**

The risk category is assigned as shown in Tab. 18. When the maximum content according to FMBV is exceeded, the category *«definite risk»* is assigned. The category *«definite risk possible»* is assigned when the average between an uncontaminated fodder plant *($C_{uncontaminated}$)* and the maximum content is exceeded (significantly raised concentration). The pollutant content of plants in uncontaminated areas are given in Tab. 19.

Tab. 18: Risk categories for fodder plant cultivation.

| Impact on fodder plant | Risk category |
|---|---|
| $c_{measured} < \frac{c_{uncontaminated} + c_{maximum\ value}}{2}$ | No risk |
| $\frac{c_{uncontaminated} + c_{maximum\ value}}{2} \leq c_{measured} < c_{maximum\ value}$ | Definite risk possible |
| $c_{measured} \geq c_{maximum\ value}$ | Definite risk |

c = concantration based on dry matter. Data on $c_{uncontaminated}$ are given in Tab. 19.

Tab. 19: Substance content of uncontaminated fodder plants (mg/kg dry matter).

| Fodder plant | As | Cd | Co | Cr | Cu | F | Hg | Mo | Ni | Pb | Sb | Se | Sn | Tl | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| barley (grain) | 0.08 | 0.05 | 0.06 | 0.29 | 4.8 | 2.9 | 0.02 | 0.6 | 0.5 | 0.1 | 0.02 | 0.04 | 0.2 | 0.04 | 38 |
| grass (in general) | 0.01 | 0.01 | 0.01 | 0.03 | 0.5 | 0.3 | 0.001 | 0.01 | 0.1 | 0.1 | 0.01 | 0.01 | 0.01 | 0.02 | 4 |
| oats (grain) | 0.11 | 0.06 | 0.09 | 0.43 | 7.2 | 2.9 | 0.03 | 0.9 | 0.8 | 0.2 | 0.03 | 0.06 | 0.3 | 0.06 | 58 |
| potato | 0.08 | 0.04 | 0.04 | 0.29 | 4.5 | 2.9 | 0.017 | 0.4 | 0.4 | 0.4 | 0.04 | 0.04 | 0.17 | 0.04 | 37 |
| lucerne | 0.01 | 0.01 | 0.01 | 0.03 | 0.5 | 0.3 | 0.001 | 0.01 | 0.1 | 0.1 | 0.01 | 0.01 | 0.01 | 0.02 | 4 |
| maize (grain) | 0.04 | 0.04 | 0.04 | 0.17 | 2.5 | 3.3 | 0.004 | 0.04 | 0.4 | 0.4 | 0.08 | 0.04 | 0.04 | 0.12 | 21 |
| rye (grain) | 0.03 | 0.03 | 0.03 | 0.14 | 2.4 | 2.9 | 0.01 | 0.3 | 0.2 | 0.1 | 0.01 | 0.02 | 0.1 | 0.02 | 19 |
| wheat (grain) | 0.11 | 0.06 | 0.09 | 0.43 | 7.2 | 2.9 | 0.03 | 0.9 | 0.8 | 0.2 | 0.03 | 0.06 | 0.3 | 0.06 | 58 |
| sugar beet (leaves) | 0.01 | 0.01 | 0.01 | 0.05 | 0.8 | 0.3 | 0.001 | 0.01 | 0.1 | 0.1 | 0.02 | 0.01 | 0.01 | 0.03 | 6 |

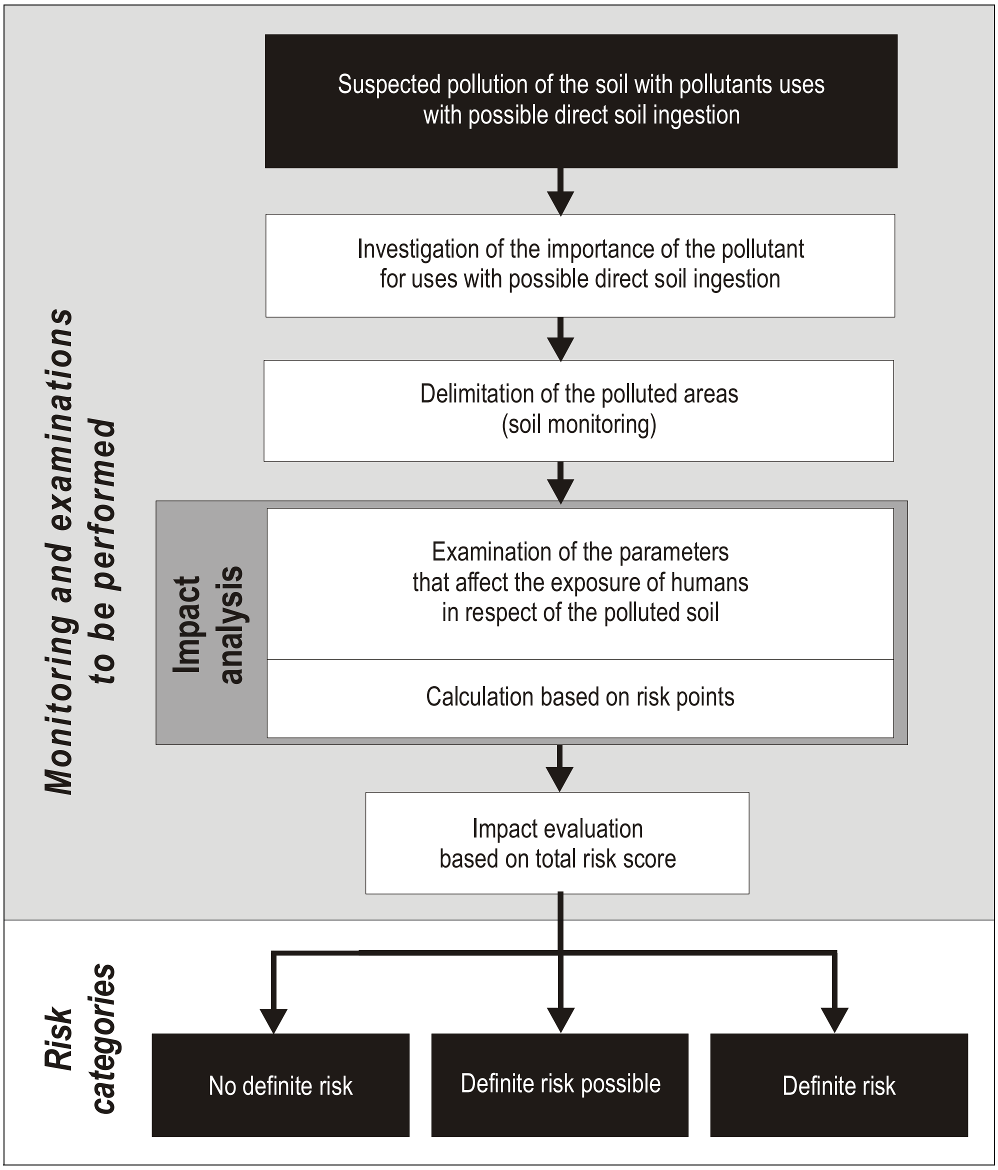
Data taken from IPE (1994), BLUME (1992), WENK *et al.* (1997), DELSCHEN & KÖNIG (1998), GISI *et al.* (1990).

The risk must be assessed for each plant species examined and each relevant pollutant. The data for plant species that accumulate the pollutant to different extents are useful for specifying appropriate measures, e.g. recommendations for use (cf. Chap. 8.2).

Where the FMBV does not specify a maximum content for the relevant pollutant, and where no suitable evaluation criteria can be found, recourse may be had to so-called threshold values for feedstuffs (cf. Annex 4).

# 6 Risk assessment for uses with possible direct soil ingestion

Fig. 6: Procedure for risk assessment for uses with possible direct soil ingestion (a detailed risk assessment is not given, as this is impracticable, cf. Chap. 6.2).



## 6.1 Expert system for uses with possible direct soil ingestion

### 6.1.1 Fundamentals

The expert system for uses with possible direct soil ingestion is designed for pollutant concentrations between the trigger and clean-up values (trigger range), and is only applicable within this range. It is based on the total pollutant content of the soil, since when soil is ingested, its total pollutant content is also ingested.

The expert system also takes account of the following parameters that influence the soil–to–human pollutant transfer:

- Age of those using the polluted area;
- Frequency of use;
- Vegetation cover.

The expert system is applicable to children's playgrounds and gardens (home gardens and allotments). Other uses with possible direct soil ingestion (e.g. sports grounds, industrial wasteland) must be assessed separately.

### 6.1.2 Impact analysis

***Monitoring of local conditions***

For impact assessment, the local conditions arising from the pollutant content of the soil and leading to human exposure must be established:

- Size of the polluted area;
- Size of the entire area in use;
- Use, e.g. children's play area (kindergarten, school grounds, playground, sports ground, park, adventure playground, etc.), home gardens and allotments;
- Users, e.g. defined or undefined users (open or closed group of persons), age of users (toddlers, small children, older children, youths, adults);
- Frequency and duration of use;
- Vegetation cover (incl. percentage cover, see comparative tables in Annex 6);
- Likelihood of changes in plant cover;
- Prohibition of access and natural or artificial barriers to access.

Recording of this data is facilitated by a monitoring form for uses with possible direct soil ingestion (cf. Annex 7). Data going beyond that necessary for the expert system is intended for assessing special conditions (cf. Chap. 8.1.2).

***Risk score G***

The expert system uses a point system for assessment. The individual parameters (exposure, age of users, frequency of use and vegetation cover) are allotted points based on the data recorded, and these summed to give a total number of points (risk score G). The risk increases with the number of points:

$$G = B + A + H + V \quad \text{(dB6.1)}$$

| | |
|---|---|
| $G$ | *Risk score;* |
| $B$ | *Impact factor (between 0 and 5 points);* |
| $A$ | *Age factor (between 0 and 3 points);* |
| $H$ | *Frequency factor (between 0 and 2 points);* |
| $V$ | *Vegetation cover factor (between 0 and 2 points).* |

***Impact factor B***

**Impact factor**

The impact factor B accounts for the influence of pollutant concentration in the soil. If the pollutant impact corresponds to the trigger value, B = 0. For the clean-up value, B = 5. Between these two points, the impact factor increases linearly:

$$B = 5 \times \frac{C_{soil} - PW}{SW - PW} \quad \text{(dB6.2)}$$

| | |
|---|---|
| $B$ | *Impact factor (points);* |
| $C_{soil}$ | *Pollutant content of the soil ([mg/kg]; total content as specified in OIS);* |
| $PW$ | *Trigger value for uses with possible direct soil ingestion as specified in OIS [mg/kg];* |
| $SW$ | *Clean-up value for children's playgrounds and/or home gardens and allotments as specified in OIS [mg/kg].* |

***Age factor A***

**Age factor**

Small children are particularly vulnerable to soil pollutants, since they play in direct contact with the soil and ingest significant quantities of soil through hand–to–mouth contact. By contrast, adults ingest very little soil (through respiration) and their body weight is greater. The risk to adults is therefore lower (cf. Tab. 20).

Tab. 20: Age factor A.

| Age category | Age | Age factor A |
|---|---|---|
| Toddlers | up to 3 years | 2 |
| Small children | >3–6 years | 1 |
| Children | >6–12 years | 0 |
| Youths and adults | >12 years | 0 |

***Frequency factor H***

**Frequency factor**

The more frequently a polluted area is used, the higher the risk (cf. Tab. 21). «Use» in this sense is taken to mean visiting the area.

Tab. 21: Frequency factor H.

| Frequency of use | Frequency factor H |
|---|---|
| More than twice per week | 2 |
| Once to twice per week | 1 |
| Less than once per week | 0 |

Vegetation cover factor

***Vegetation cover factor V***

Exposure also depends on the vegetation cover of an area. Full plant cover reduces the risk, since this reduces soil contact. For effective protection, vegetation cover must be relatively high, since, as experience shows, children prefer to play on bare ground. An estimate should be made of the percentage of the polluted area over which the vegetation prevents direct soil contact (cf. Tab. 22). Often, the soil is accessible under shrubs and trees where ground vegetation is absent. An aid to estimating vegetation cover is given in the tables in Annex 6.

Tab. 22: Vegetation cover factor V.

| Cover | Percentage cover | Vegetation cover factor, V |
|---|---|---|
| Poor | <75 % | 2 |
| Moderate | 75–90 % | 1 |
| Good | >90 % | 0 |

### 6.1.3 Impact evaluation

The risk category is assigned based on the risk score as given in Tab. 23.

Tab. 23: Risk categories for direct soil ingestion.

| Risk score G = B + A + H + V | <3 | 3–<5 | ≥5 |
|---|---|---|---|
| Risk category for toddlers, small children and older children (up to 11 years old) | No risk | Definite risk possible | Definite risk |
| Risk category for youths and adults (from 12 years of age onwards) | No risk | Definite risk possible | Definite risk possible |

The assignment of risk categories differs for children, youths and adults. For youths and adults, recommendations for use can be given that will in all probability be followed, and these should normally suffice to avoid any risk. Thus obligatory measures such as restrictions of use, which would otherwise have to be taken for the risk category *«definite risk»,* are not necessary.

Examples of the application of this expert system to children's playgrounds are given in Annex 1C and for home gardens in Annex 1D. For uses with possible direct soil ingestion, a pre-programmed spreadsheet is available.[6]

## 6.2 Detailed risk assessment for uses with possible direct soil ingestion

As opposed to the use categories food plant cultivation (cf. Chap. 4) and fodder plant cultivation (cf. Chap. 5), a detailed risk assessment for uses with possible direct soil ingestion proves impracticable. The reason for this is that impact measurements on humans themselves – in this case on children – are scarcely possible.

As an alternative to the expert system described above, analytical methods are available, e.g. the *«UMS model»* of the UBA. In this system, if the influence of data variability and uncertainty can be assessed (so-called *«Monte-Carlo simulation»* methods).

SAEFL (2004) provides an overall review of quantitative analytical methods for estimating the risk to humans and the environment. However, it is emphasized that in the absence of specialist knowledge, a careful assessment of the data and a plausibility assessment of the results, the use of these methods can easily lead to meaningless results. The results should therefore be subjected to critical evaluation based on the quality criteria laid down specifically for the performance of quantitative risk assessment.

[6] cf. excel format: http:\\www.environnement-suisse.ch→thèmes→sol→mise en œuvre de l'OSol→ manuel évaluation de la menace.

# 7 Procedures in the absence of regulatory values

**Pollutants according to OIS**

The OIS stipulates regulatory values only for frequently occurring pollutants that may present a risk with the uses concerned. These are: Pb, Cd, Cu, Zn, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB) and dioxins/furans (PCDD/F). The OIS does not, however, specify all the regulatory values of these pollutants.

**Assessment of other pollutants**

Where pollutants have been identified in a soil for which the OIS contains no guide, trigger or clean-up values, an assessment must be made whether the pollutants represent a definite risk to humans, animals or plants (exposure paths: cf. Chap. 3.3). Data on environmental pollutants are given in EIKMANN *et al.* (1999; updatable handbook).

Where a pollutant is relevant to the use concerned, data from EIKMANN & KLOKE (1993) may be used as reference values for risk assessment (cf. Annex 8). These comprise three so-called «Bodenwerte» (BW; «soil values») per pollutant and use category, which are comparable to the regulatory values in the OIS.

**BW I:** Basic value (background value), comparable to the **guide value** in OIS;
**BW II:** Trigger value (target value for clean-up), comparable to the **trigger value** in OIS;
**BW III:** Intervention value, comparable to the **clean-up value** in OIS.

Using these values, a risk assessment can be carried out under the specific conditions applying to each use category (cf. Chap. 4–6). Where no reference values are specified by EIKMANN & KLOKE (1993), these may be taken from equivalent international criteria or the specialised literature. In this case, detailed examinations are required. The list of reference values given in the Manual may be extended periodically based on current knowledge.

When using values from EIKMANN & KLOKE (1993), note that the sampling depths and extraction methods assumed there differ from those of the OIS (e.g. extraction of heavy metals using aqua regia in Germany, as opposed to 2 M $HNO_3$ in the OIS). This can in certain cases lead to different results, and must be taken into account. Information on the extraction and measurement procedures used in Germany are contained in the German *Bundes-Bodenschutz- und Altlastenverordnung,* and also in ROSENKRANZ *et al.* (cf. updatable handbook, *code no. 8005).*

# 8 Measures

## 8.1 Basic principles in determining measures

### 8.1.1 Type and stringency of measures

**Precautionary measures**

Irrespective of whether a definite risk exists or not, the measures specified in Art. 8 OIS must be taken when the guide values are exceeded to prevent a further rise in soil pollution (determination of the cause, emission control measures).

Where the risk is categorised as *«definite risk»* or *«definite risk possible»,* the cantonal authorities responsible for enforcement must take the following action:

**Recommendation on use**

A ***recommendation on use*** is the least stringent measure. It is intended to make users aware of the risk and advise on appropriate action to avoid it. Recommendations on use can suffice where the following conditions are met:

- The user group is known, so that a recommendation on use can be made to it.
- The risk is categorised as *«definite risk possible».*

**Restriction and prohibition of use**

A ***restriction of use*** prohibits only those activities or actions that cause a direct risk to humans, animals or plants. However, the previous use may be retained.

In distinction, a ***prohibition of use*** prohibits all activities or actions associated with a particular use. In the case of the obligatory measures *restriction of use* and *prohibition of use,* the risk category is *«definite risk».*

**Appropriateness of the means**

Restriction of use and prohibition of use are measures under (police) enforcement legislation that affect the rights of those concerned. The authorities must not apply more stringent enforcement procedures than the circumstances demand (appropriateness: cf. Art. 42 *Federal Law relating to Administrative Procedures; SR 172.021).* The measures underlie the following conditions:

- The measure must be appropriate to avoid the existing risk (expediency).
- The measure must not go beyond what is required, that is to say it is not possible to achieve the protection objective by a less stringent measure (appropriateness). Thus it is preferable, where possible, to approve an activity under certain conditions rather than to prohibit it. In effect, this requires that the measures be graduated. Furthermore, the measures must only be directed towards those responsible (in law: the perpetrator).
- The measure must be appropriate to the intended objective (cost-benefit ratio). The restrictiveness of the intervention must be commensurate with the importance of the objective pursued. The more restrictive the intervention, the higher the interest in the pursuit of the objective must be. As an example, a prohibition to use a children's playground can be appropriate when applied to avoid a definite risk to the health of children.

### 8.1.2 Special conditions

In determining necessary measures, those special conditions of the case at hand having an influence on the extent of the risk, but not already included in the risk assessment, must be considered. Any of the following circumstances may be involved:

***General conditions for all types of use***

**Impact on small part of the total area**

- The risk can be reduced if the exposed area is small (nominal value: <20%) in comparison to the total area for this use – usually an entire plot. A reduction in the risk can occur for example with fodder plant cultivation for livestock if only a small part of its total fodder comes from the exposed area, or, for food plant cultivation, where mixing of the harvested material occurs automatically. Here, it is important that for the characteristic use to which the site is put, the impact on the subjects of protection declines *of itself.* Intentional mixing of harvested materials that are contaminated to different extents with a view to reducing the contamination below the maximum value is not permitted. Also, it does not make sense to reorganize the plots simply to reduce the impact on the subjects of protection. The primary objective should be to reduce the impact on the subjects of protection by applying measures to the exposed area itself.

**Impact for short periods**

- The regulatory values in Annex 1 OIS are designed to cover continuous exposure over longer periods. The risk is further reduced when the subject of protection is only exposed for a relatively short period. This can, for example, be the case for Alpine pastures that are used only during short periods of the year.

**Impact from several pollutants**

- The total risk from soil pollution can increase where several pollutants contribute to the risk.

**Impact via several exposure paths**

- The total risk from soil pollution is increased where the impact occurs via several exposure paths (e.g. via food plants and oral ingestion by children in home gardens).

***Special conditions in food and fodder plant cultivation***

**Own consumption**

- Where food plants and animal products produced on a polluted area are for own consumption, this increases the risk. For those producing their own food, the proportion of self-produced food can be high and must be taken into account.

***Special conditions for uses with possible direct soil ingestion***

**Use**

- Use by a well defined group of persons is easier to regulate than use by an undefined group. The risk in the former case is generally less acute.
- Restriction of access: where access is not restricted, the risk is higher.
- Barriers such as fencing, thorny hedges, etc., around the area reduce the risk.

The above list contains only a selection of possible conditions. Also, the conditions pertaining in a particular case cannot always be foreseen in advance.

### 8.1.3 Procedure for the determination of measures

The restrictiveness of the measures depends on the extent of the risk and the special conditions in each individual case. In general, measures are assigned to the risk categories as given in Tab. 24.

Tab. 24: Assignment of measures to risk categories.

| Risk category | Measures |
|---|---|
| No definite risk | → Monitoring (Art. 4 Para. 1 OIS) and emission control (Art. 8 OIS) |
| Definite risk possiblev | → Recommendations on use; additionally, monitoring (Art. 4 Para. 1 OIS) and emission control (Art. 8 OIS) |
| Definite risk | → Restriction and prohibition of use, if necessary clean-up; additionally, monitoring (Art. 4 Para. 1 OIS) and emission control (Art. 8 OIS) |

The special conditions must be taken into account in determining the measures in each individual case (cf. Chap. 8.1.2). These are to be considered as additional criteria that can modify the type and restrictiveness of the measures. The authorities› room for manoeuvre derives primarily from their freedom to include special conditions in individual cases. Whenever possible, measures should be agreed with those concerned, since in this way they are more likely to meet with acceptance.

## 8.2 Specific measures for the reduction or elimination of risk

### 8.2.1 Measures for food and fodder plant cultivation

The following measures can be appropriate depending on the risk category:

***Recommendations on use:***

- Abstention from the use of fertilisers and plant protection products that can cause soil pollution.
- Lime dressing at low pH values (particularly in the case of inorganic pollutants) and measures to increase the content of organic substance in the soil (particularly with organic pollutants). With fodder plant cultivation, these measures are only effective when the pollutant ingestion occurs predominantly via the plants themselves (root uptake).
- For fodder plant cultivation, avoidance of overgrazing of the polluted area.
- With fodder plant cultivation, reduction of crop soiling during harvesting (harvesting as far as possible under dry soil conditions, haymaking in place of mown grass), assuming that this is the main ingestion path.
- With fodder plant cultivation, reduced ration of contaminated plants.

***Obligatory measures (restriction and prohibition of use)***

- Restriction of cultivation to food and/or fodder plants that accumulate the given pollutant to a lesser extent (cf. Tab. 6).
- With fodder plant cultivation, prohibition of grazing of the polluted area (i.e. restriction to cultivation of plants that are harvested). This measure is especially appropriate when direct oral ingestion outweighs ingestion via contaminated fodder plants.

- With fodder plant cultivation, restriction of use of the area concerned to less sensitive livestock.
- Restriction to less sensitive use, on condition that this is permissible under development planning regulations.
- Prohibition of use.

### 8.2.2 Measures for uses with possible direct soil ingestion

***Recommendations on use:***
- Planting and/or tending of the vegetation cover to prevent soil contact (i.e. lawns).

***Obligatory measures:***
- Prohibition of use, and possible additional prohibition of access or fencing off.

### 8.2.3 More far-reaching measures for all uses

**Clean-up**

Measures to reduce the pollution (decontamination) can only be required when the clean-up values are exceeded, and only in areas in which horticultural, agricultural or forestry uses have been specified in development planning (Art. 10 Para. 2 OIS). Where the trigger value is exceeded, soil protection legislation only allows clean-up as a measure (e.g. by replacing the contaminated soil) to be recommended. Where clean-up is performed, it is recommended to reduce the contamination below the trigger value, thereby ensuring that an additional risk assessment and possible accompanying restrictions on use will not be required.

## 8.3 Monitoring

The cantons must monitor areas in which the trigger values are exceeded. The measures required to do so depend on the particular case.

**Monitoring in cases of definite risk**

Where a definite risk has been established, monitoring can cover both the absolute soil pollution (pollutant content) and other parameters influencing the risk. The following measures can be considered depending on the case at hand:
- Monitoring of the pollutant content of the soil and/or of soil characteristics (e.g. pH value) at suitable intervals, provided that the pollutant content is expected to change.
- Monitoring of the pollutant content of products (with food and/or fodder plant cultivation).
- Monitoring of use.
- Monitoring of the vegetation cover (for uses with possible direct soil ingestion).
- Reiteration of recommendations on use at suitable intervals.
- Regular checks of restrictions and prohibitions of use.

**Monitoring where no definite risk exists**

Where according to the risk assessment there is no definite risk to humans, animals or plants, the area concerned must nevertheless be monitored where the trigger value has been exceeded, to exclude any risk. Monitoring can, for example, take the form of an entry in a register. Here, monitoring is normally only required if a significant change in the risk situation is to be expected, e.g. by virtue of a change in use.

## 8.4 Measures with soil pollution at greater depth

**Soil pollution deeper than 20 cm**

Soil protection legislation is also applicable to pollution at greater depths, i.e. that does not extend to the surface. This is subject to the proviso that the pollution lies within the region penetrable by roots, i.e. within the B horizon (that is to say, not in the substratum, i.e. the C horizon), and an impact on humans, animals or plants may be expected (cf. Chap. 2). Where the trigger value is only exceeded at depths greater than 20 cm, an examination must be made for the case at hand whether this represents a definite risk (for example with deep-rooted plants). It must also be determined whether a definite risk to humans, animals or plants could occur in the future. This could be the case if the polluted soil should find its way into the top 20 cm of the soil at some future time, for example through soil erosion, bioturbation, other cultivation methods, or through building projects.

If it is anticipated that the pollution could lead to reduced soil fertility (Art. 4 Para. 1 OIS), or, indeed, to a definite risk to humans, animals or plants (exceeding of trigger value, cf. Art. 9 OIS), the pollution must be monitored. The measures required depend on the individual case.

## 8.5 Responsibilities and completion dates[7]

### 8.5.1 Responsibility and procedure

**Who is responsible?**

For more stringent measures as specified in Art. 34 LPE for polluted soils, the cantons are responsible (cf. Art. 13 OIS). The cantons must specify the responsibility and procedures (cf. Art. 36 LPE). They may entrust the municipalities with certain soil protection tasks, namely those concerning the imposition and control of restrictions and prohibitions of use. However, regarding proper enforcement of Art. 34 LPE, the cantons remain directly accountable to the Confederation.

Where the soil impact arises from a contaminated site as specified in Art. 2 OCS, the provisions of the OCS apply.

[7] The information in Chapter 8.5 is based on the commentary in TSCHANNEN (1999) on Article 34 LPE (cf. notes on p. 20ff.). For information on the polluter pays principle in conjunction with measures under soil protection legislation, also see HEPPERLE (2001).

### 8.5.2 Imposition of measures

**Who are the measures directed to?**

The measures for the protection of public health and the environment come under (police) enforcement legislation. For this reason, they are directed against the person directly responsible for the illegal condition (perpetrator). Since the impact to be remediated arises from the soil, the following persons are rated as perpetrators (depending on the use involved in any particular case):

- the owner of the polluted soil;
- the land user;
- any person who markets the products from the polluted soil that represents a risk to health.

If owing to lack of financial means the perpetrator is not in a position to eliminate an imminent risk, the authorities themselves order the necessary precautionary and remedial measures by way of direct enforcement without delay (cf. Art. 59 LPE).

### 8.5.3 Imposition of costs

**Who must carry the costs?**

The purpose of the measures taken by the cantons to protect against definite risks is to fulfil their responsibilities under Art. 34 LPE. Costs are therefore imposed according to the general polluter pays principle as specified in Art. 2 LPE. The costs of precautionary and remedial measures are imposed as specified in Art. 59 LPE, and those of the proceedings as specified in the applicable legislation on administrative procedures. Where the soil impact arises from a contaminated site as specified in Art. 2 OCS, costs are imposed as laid down explicitly in Art. 32d LPE.

### 8.5.4 Compensation

**Can compensation be expected?**

Restrictions and prohibitions of use according to Art. 34 Para. 2 and 3 LPE represent public law restrictions on the right of property. However, the municipalities are not liable to provide compensation, since the restrictions and prohibitions are imposed only to avoid a definite risk to the health of humans, animals or plants. The measures therefore answer simply to the requirements of (police) enforcement in the narrower sense.

### 8.5.5 Implementation periods

**How quickly must action be taken?**

Where the ***guide values are exceeded,*** the cantons must take measures within five years after the soil impact was determined. The implementation periods are laid down in accordance with the urgency of the particular case (cf. Art. 8 Para. 4 OIS).

For measures relating to ***exceeding of trigger and clean-up values,*** no implementation periods are specified in federal law. Nonetheless, the principles on which general (police) enforcement legislation is based require that in cases where the risk has been established as specified in Art. 34 Para. 2 and 3 LPE, the measures be introduced without delay and with due regard to the urgency of the case at hand.

# Annexes

# Annex 1

## Examples of risk assessment

D The following four examples are provided to elucidate and simplify the procedure for risk assessment using expert systems. The examples (which are fictive) concern four typical uses:

**A** Use category **food plant cultivation** (agriculture and horticulture);
**B** Use category **fodder plant cultivation;**
**C** Use category **uses with possible direct soil ingestion;**
**D** Use **home gardens,** i.e. combined form of A and C.

### A Risk assessment for food plant cultivation (agriculture and horticulture)

#### Example: Cd exposure in cereals cultivation

**Basic situation**

On land used for arable purposes, a Cd content in the soil of 6.0 mg/kg was determined (sampling depth 20 cm). Based on a soil analysis, a pH value of 6.4 ($CaCl_2$, 0.01 M), an organic substance content of 4.5% and a clay content of 19% were determined. The land is used mainly for the cultivation of cereals (foodstuffs) for the market, whereby wheat is the present crop.

**Calculations based on the expert system**

Calculations based on the expert system for food plant cultivation (cf. Tab. 25) show that a Cd content of only slightly above the Cd trigger value leads to assignment of the risk category *«definite risk»*. The reasons for this are to be found in the relatively high correction factor T and the substantial mobility of Cd – the latter also applying at high pH values.

Tab. 25: Calculations for food plant cultivation (agriculture and horticulture).

| Factor | Points | Notes |
|---|---|---|
| Impact factor B | 0.7 | cf. Equation (N4.2), Chapter 4.1.2 |
| Mobility factor M | 2 | Sum of the relative linkage forces (cf. Fig. 4, Chap. 4.1.2): 4 points, namely 4 pt. for pH value 6.5 (pH value 6.4 rounded up) and 0 pt. each for content of organic substance and clay |
| Plant type factor P | 2 | Plant type factor for wheat – a plant with high uptake (cf. Tab. 6, Chap. 4.1.2) |
| Correction factor T | 0.5 | Correction factor T for Cu (cf. Tab. 15, Chap. 5.1.2) |
| Risk score G = B+M+P+T | 5.2 | Impact evaluation: Assignment of risk category *«definite risk»* (above 5 pt.; cf. Tab. 8, Chap. 4.1.3) |

**Considerations, special conditions and measures**

On the basis of this risk assessment using an expert system, the cultivation of food plants having a high Cd uptake (wheat and oats) is rated as being an excessive risk to health, and must therefore be terminated. Restriction of use is therefore unavoidable.

In this example, the Cd content of the wheat currently under cultivation must be analysed before the wheat is marketed. If the Cd content of the wheat lies above the maximum FIV content of 0.2 mg/kg fresh weight, it must not be used for the production of foodstuffs. Provided that the Cd content does not exceed the maximum value specified in the FMBV (1 mg/kg in fodder at 88% dry matter content), it can, however, be used as fodder.

In general, however, the use category food plant cultivation is still possible on the land concerned. Thus there is no reason why food plants having an average or low Cd uptake should not continue to be cultivated on the land. For these plants, and assuming factors P = 1 or 0 (cf. Tab. 26), the risk score amounts to 4.2 or 3.2 respectively. This results in assignment of the category *«definite risk possible»* (3–<5 points). For cereal crops, rye, barley and maize fall in this Cd uptake category. Where the cereals cultivated are not consumed by the owners themselves (in which case they would account for a high percentage of total food consumption), this restrictive condition can be omitted.

Thus the most effective recommendation for use would be to grow only food plants having a low Cd uptake. It also makes sense to raise the humus content of the polluted land. This can be done by sowing green manure plants (e.g. phacelia, mustard) after harvesting the cereals. A higher humus content is known to lower Cd mobility (cf. Fig. 4). In general, Cd mobility is also lowered at higher pH values. It is, however, questionable whether it would be possible to raise the existing, relatively high, pH value of 6.9 by increasing the lime content.

**Notes**

If the owner of the land is not in agreement with the assessment (resulting in restriction of use), he/she may choose to have a more detailed risk assessment performed than is possible with the expert system. In this case, food plants having a high Cd uptake must be investigated in more detail (cf. Tab. 6). The pollutant uptake of plants often differs depending on the type of plant and the weather conditions. Furthermore, it is hardly possible to obtain a reliable assessment from plant studies carried out over a single growth period.

### B Risk assessment for fodder plant cultivation

#### Example: Cu contamination of a meadow (use for grazing and haymaking for sheep and cattle)

**Basic situation**

A Cu content in the soil of 215 mg/kg was determined in a meadow (sampling depth 20 cm). The pollution corresponds to that frequently occurring in former vineyard soils. An analysis of the soil properties showed a pH value of 6.3, a humus content of 6.0% and a clay content of 28%. The land is also used for cattle grazing and for hay for the cattle. The landowner may wish to use the meadow in future for sheep grazing.

**Calculations using the expert system**

Calculations using the expert system fodder plant cultivation and applying the FMBV maximum content of 35 mg/kg (for cattle cf. Tab. 12) show that direct soil ingestion – despite its relatively small percentage – is responsible for the major part of the Cu exposure of the livestock. Also note that this is the most frequent form of exposure with fodder plant cultivation.

Tab. 26: Calculations for fodder plant cultivation.

| Factor | Points | Notes |
|---|---|---|
| Soil contribution factor E | 1.2 | cf. Equation (F5.2), Chapter 5.1.2; an average value of 2.5 % was used for direct soil ingestion for grazing under dry conditions (cf. Tab. 13) |
| Impact factor for plant uptake B | 0.6 | cf. Equation (F5.3), Chapter 5.1.2 |
| Mobility factor M | 0 | Sum of the relative linkage forces (cf. Fig. 4, Chap. 4.1.2): 6 points, namely 5 points for pH value 6.5 (pH value of 6.3 rounded up), 1 point for organic substance content and 0 points for clay content |
| Plant type factor P | 1 | Plant type factor for grass – a plant with average uptake (cf. Tab. 14, Chap. 5.1.2) |
| Correction factor T | 0 | Correction factor T for Cu (cf. Tab. 15, Chap. 5.1.2) |
| Risk score G = E+B+M+P+T | 2.8 | Impact evaluation: This results in assignment of risk category *«no definite risk»* (up to <5 points; cf. Tab. 17, Chap. 5.1.3) |

**Considerations, special conditions and measures**

For cattle, the category *«no definite risk»* applies under the present conditions of use. Under wet weather conditions, the situation is slightly different. Here, the percentage of soil in the fodder lies between 10 and 15% (average value 12.5%; cf. Tab. 13). This would result in a soil contribution factor E of 6.1, leading to a risk score of 7.7 (category *«definite risk possible»).*

Recommendations for use with the object of influencing the soil properties would not be appropriate in this case. Here, the soil properties have only a minor influence on the Cu uptake of livestock. Indeed, a possible (hypothetical) increase in the pH value would increase the mobility of Cu, thereby raising the Cu content of the grass (cf. Fig. 4). It is, however, advisable to recommend that the polluted land should be used only under dry conditions, since in this case the soil contribution is smaller (cf. Tab. 13). Furthermore, the landowner should be advised to apply any fodder additives containing Cu (growth promoters), if at all, very sparingly.

A possible future use as sheep pasture must be judged differently from the present use. This is partly due to the greater sensitivity of sheep to Cu pollution (maximum content according to FMBV: 15 mg/kg; cattle 35 mg/kg). Also, grazing sheep ingest significantly more soil than cattle (cf. Tab. 13).

In the present case, therefore, even under favourable conditions (dry soil), the category *«definite risk»* would have to be assigned to sheep (risk score 15.9). Furthermore, although the maximum content specified in the FMBV only applies to complete feed (i.e. exclusive use of a fodder), even where the critical values for livestock fodder given by BLUME (1992) are applied, and a value of 30 mg/kg is assumed in this case for the individual feeds, a risk score of 8.8 still results. This corresponds to the category *«definite risk»*. There is no question, therefore, of using the land as sheep pasture.

**Notes**

If the owner of the land is not in agreement with the assessment, he/she may choose to have a more detailed risk assessment performed than is possible with the expert system. In this event, it would not be sufficient merely to analyse the animal products (milk, meat). Exposure to Cu not only endangers the health of humans who consume the animal products, but also that of livestock. This is because animals (for example ruminants) are significantly more sensitive to Cu than humans.

For the same reason, the question of the percentage of own consumption (as special condition) is not relevant in the present case. Here, an analysis of the pollutant content of the grass would not suffice, since the sheep are subject mainly to exposure through direct soil ingestion. Sheep grazing on meadows contaminated with Cu should therefore be avoided. A detailed risk assessment would only be possible by allowing sheep to graze on the meadow concerned for a trial period.

## C Risk assessment for uses with possible direct soil ingestion

### Example: PAH exposure of a children's playground

**Basic situation**

A PAH pollution of the soil of 39 mg/kg (sampling depth 5 cm) was determined for a children's playground. A monitoring of the site showed that the playground is also used by toddlers and young children (1–5 years old) accompanied by their mothers. However, they never visit the playground more often than once or twice per week. This is not the case for older children, who attend more frequently. The playground is largely covered by lawns and well spaced trees. However, in the vicinity of play installations, there are areas of uncovered ground. These amount to an estimated 10–15% of the total playground area. The playground is public and freely accessible.

**Calculations using the expert system**

Calculations using the expert system for uses with possible direct soil ingestion give a maximum risk score of 4.6 both for fairly frequent use by children of 7 years of age and older, and for once or twice-weekly use by children of 4–6 years of age.

The calculations show clearly that in the low trigger value range, the age factor plays a dominating role. The reason for this is that the likelihood of soil ingestion (difficult to determine in quantitative terms) is greatest for toddlers and small children, who tend to slide about when playing.

Tab. 27: Example of use with possible direct soil ingestion (children's playground).

| Factor | Points | Notes |
|---|---|---|
| Impact factor B | 1.6 | cf. Equation (dB6.2) |
| Age factor A | 2 | Age factor for toddlers (up to 3 years old; cf. Tab. 20, Chap. 6.1.2) |
| Frequency factor H | 1 | Frequency factor for once to twice-weekly use (cf. Tab. 21, Chap. 6.1.2) |
| Vegetation cover factor V | 1 | Vegetation cover factor for percentage cover of 75–90 % (cf. Tab. 22, Chap. 6.1.2) |
| Risk score G = B+A+H+V | 5.6 | Impact evaluation: this results in assignment of risk category *«definite risk»* (from 5 points onwards; cf. Tab. 23, Chap. 6.1.3) |

**Considerations, special conditions and measures**

The playground can no longer be used by children up to 3 years old, since for these, the category *«definite risk»* would result for frequent use. Further, an assessment should be made as to whether the vegetation cover could (at times) lie below 75%, since this value was based on an estimate. If so, children up to 6 years old could also be at risk *(«definite risk»* for once to twice-weekly use).

This must be decided depending on the individual circumstances. For example, the experience of the municipal authorities may help to establish the degree of vegetation cover that existed in past years.

In a further example, the playground belongs to a holidaymaker's hotel and is closed to the public. Children use it only for short periods during their stay. Under the assumption that the children of hotel personnel do not use the playground, no long-period ingestion of pollutants occurs. Note here that the regulatory values in the OIS apply to possible direct soil ingestion for long-period use.

In the present case of short-period use, the soil protection authority can exercise a certain margin of decision in justified cases. The measures described above can be modified to suit the special conditions. Also, the playground can be used by toddlers provided the ground is covered as fully as possible, i.e. at least to 90%, with vegetation (lawns).

**Notes**

If the owner of the land is not in agreement with the assessment, he/she may choose to have a more detailed risk assessment performed than is possible with the expert system. This is, however, a difficult task with children's playgrounds, since for small children (for example) it is not easy to measure the quantity of pollutants ingested. In such cases, the use of simulation methods can be considered (cf. Chap. 6.2).

## D Risk assessment for use of home gardens

### Example: Lead pollution of a home garden

**Basic situation**

A Pb content of 380 mg/kg (sampling depth 20 cm) was determined in the vegetable bed of a home garden. The vegetable bed covers approximately one-third of the total area, the rest consisting of a lawn. A range of food plants, for example lettuce, kohlrabi, carrots, marrows and pumpkins, is grown. To reduce costs, the soil properties are assessed on site, i.e. no laboratory analyses are performed. The approximate procedure gave a pH value of 7 (quick test), an estimated humus content of 10% and an estimated clay content of 35%.

The quantity of self-produced vegetables is quite small in comparison to total consumption, and was estimated by the owner at approximately 20%. The family, which uses the garden almost daily in summer, includes children between the ages of 9 and 13 years.

**Calculations using the expert system**

Contrary to the above examples, with gardens two use categories must be considered owing to the different exposure paths, namely food plant cultivation and uses with possible direct soil ingestion. Furthermore, the regulatory values for gardens differ partly from those for agricultural food plant cultivation and for children's playgrounds.

The results of calculations using the expert system for food plant cultivation are shown in Tab. 28. The results also illustrate that the chemical behaviour of Pb is quite different from that of Cd (cf. example in Annex 1A). With comparable soil characteristics, the mobility of Pb is known to be significantly lower than for Cd. The same applies to the correction factor T.

Tab. 28: Calculations for food plant cultivation (home gardens).

| Factor | Points | Notes |
|---|---|---|
| Impact factor B | 1.1 | cf. Equation (N4.2), Chapter 4.1.2 |
| Mobility factor M | 0 | Sum of the relative linkage forces (cf. Fig. 4, Chap. 4.1.2): 6 points (4 points for pH value of 7, and 1 point each for organic substance and clay content) |
| Plant species factor P | 2 | Plant species factor for lettuce, being representative of plants with high uptake (cf. Tab. 6, Chap. 4.1.2) |
| Correction factor T | 0 | Correction factor T for Pb (cf. Tab. 7, Chap. 4.1.2) |
| Risk score G = B+M+P+T | 3.1 | Impact evaluation: this results in the assignment of risk category *«definite risk possible»* (from 3–<5 points; cf. Tab. 8, Chap. 4.1.3) |

The calculations using the expert system uses with possible direct soil ingestion for the nine-year-old child – assuming the most unfavourable conditions – lead to assignment of risk category *«definite risk possible»* (cf. Tab. 29).

Tab. 29: Calculations for uses with possible direct soil ingestion (home gardens).

| Factor | Points | Notes |
|---|---|---|
| Impact factor B | 0.6 | cf. Equation (dB6.1), Chapter 6.1.2 |
| Age factor A | 0 | Age factor for children from 7 years of age upwards, youths and adults (cf. Tab. 20, Chap. 6.1.2) |
| Frequency factor H | 2 | Frequency factor for more than once to twice-weekly use (cf. Tab. 21, Chap. 6.1.2) |
| Vegetation cover factor V | 2 | Vegetation cover factor for percentage cover of <75 % (cf. Tab. 22, Chap. 6.1.2) |
| Risk score G = B+A+H+V | 4.6 | Impact evaluation: this results in the assignment of risk category *«definite risk possible»* (from 3 points upwards; cf. Tab. 23, Chap. 6.1.3) |

**Considerations, special conditions and measures**

The data obtained above show that the cultivation of food plants does not attain the category *«definite risk»*. It should, however, be borne in mind that the soil characteristics were estimated. It is therefore necessary to establish at what estimated levels small uncertainties would lead to a different result. A large error of 10% in the estimated clay content (i.e. clay content <25%) would be required for assignment of a different category. Also, the estimated humus content could be reduced to below 8% (in place of 10%) without affecting the risk score.

With quick tests, it is possible for the measured pH value to vary by ±0.5 pH units from the true value. Should this result in a true pH value of 7.5, this would not affect lead mobility. If the true pH value amounted to 6.5 units, the mobility would in fact be lower. Thus a *«definite risk»* would not result for cultivation of any type of plant. As a precautionary measure, the landowner should, however, be advised to avoid cultivation of food plants having a tendency to accumulate lead (e.g. lettuce and carrots).

The calculations using the expert system direct soil ingestion lead to assignment of the risk category *«definite risk possible»*. However, in this case the uncovered ground is a vegetable bed, i.e. not a playing area as such. A youth of 13 years can be expected to follow advice to make proper use of the garden, and this would also apply in most cases to a child of 9 years of age. For these reasons, recommendations for use are appropriate.

In distinction, the risk category *«definite risk»* might result for small children up to the age of 6 depending on the circumstances. Thus for small children and toddlers, the garden in this example is unsuitable as a place to play. Moreover, to cover future changes in ownership, this circumstance must be recorded in writing (e.g. by entry in a register). In the present case, an improvement in the exposure situation cannot be expected to take place even in the long term.

**Notes**

If the owner of the land is not in agreement with the assessment, he/she may choose to have a more detailed risk assessment performed than is possible with the expert system. Further, the difficulties in assessing direct soil ingestion are similar to those in example Annex 1C.

# Annex 2

## Pollutants

In the following, a summary of available information on a range of pollutants is provided. The pollutants in question are those for which the annexes in the OIS specify trigger and clean-up values.[8]

### A Lead (Pb)

**Effects of Pb on humans**

The main impact of lead on humans takes place via direct inhalative and oral soil ingestion. Lead exposure causes an increase in the lead content of the blood, leading to harmful effects on health. Initially, this results in changes in blood count and the urine. Particularly for children, who ingest excessive quantities of soil when playing (so-called pica behaviour), and when the lead pollution of the soil is high, this can result in the middle term (months) in encephalopathy and anaemia. Also, with long-term exposure (years), negative effects on mental capability have been observed, and these can be irreversible.

**Effects of Pb on animals**

With animals, very high lead exposure leads to clinical syndromes such as hyperactivity, disorientation, impaired motor function and blindness. Exposure of this nature can lead to death. By contrast, impairment to human health through the consumption of animal products contaminated with lead is of secondary importance.

**Pb in food plants**

Lead accumulates only to a slight extent in plants. The ratio of plant content to total content in the soil amounts to 0.01:1 to 0.1:1. A knowledge of the accumulation potential of various types of vegetables and fruit (cf. Tab. 6) is helpful in making suitable recommendations to reduce human exposure from food plants containing lead.

### B Cadmium (Cd)

**Effects of Cd on humans**

The dominant source of human exposure to Cd – a highly toxic element – results from the food chain. Moreover, smokers are subject to approximately twice the Cd exposure of non-smokers. In the body, Cd accumulates mainly in the kidneys, the liver and the muscles. With lifelong exposure to Cd, malfunctioning of the kidneys can occur.

In Switzerland, the average ‹exploitation› of the PTWI value for heavy metals (Provisional Tolerable Weekly Intake, FAO/WHO)[9] for Cd amounts to 20%, the

[8] Detailed information on these and other pollutants can be obtained from EIKMANN *et al.* (1999; updatable handbook for risk assessment (German: «Gefährdungsabschätzung», concerning mainly the toxicity of pollutants) and SCHEFFER & SCHACHTSCHABEL (2002, particularly concerning the occurrence and behaviour of pollutants in the soil). Where agricultural and horticultural uses are concerned, *Agroscope FAL Reckenholz* and *Agroscope RAC Changins* can also be consulted.

[9] WHO/FAO, 2003, *«Summary and conclusions of the Joint FAO/WHO Expert committee on food additives (JECFA)»* – 61st meeting in Rome, 10–19 June 2003; see: Annex 4 on Cd.

highest for any country (BAG 1991). Any additional exposure to Cd, for example from food plants, should therefore be kept as low as possible.

**Effects of Cd on animals**

As with humans, animals are exposed to Cd principally via their food. However, loss of productivity and health symptoms only occur at very high Cd exposure in individual animals. Where humans consume livestock products contaminated with Cd (particularly kidneys and liver) this leads indirectly to a risk to health. This is accounted for in foodstuffs legislation by the specification of threshold values for animals.

**Cu in food plants**

Cd accumulates heavily in plants. The ratio of plant content to total content in the soil amounts to up to 10:1. Plant species differ significantly in their accumulation potential. In food plant cultivation, the maximum content specified in the FIV is exceeded most frequently for Cd.

### C Copper (Cu)

**Effects of Cu on humans**

Copper is essential to human life and is toxic only at higher concentrations. When taken up with food, Cu mainly accumulates in the liver and the brain. However, chronic Cu toxicity hardly occurs in humans, since this heavy metal has no general accumulation characteristics (SCHNEIDER & KALBERLAH 2000; SCHEFFER & SCHACHTSCHABEL 2002). In distinction, cases of intoxication have occurred for short-term exposure following oral ingestion.

Effects concern primarily the gastro-intestinal tract. At sufficiently high doses, the liver and kidneys may also be affected, and this can be fatal. Cu dust can cause irritation effects via inhalative ingestion, but this only occurs under extreme exposure (special workplace conditions; cf. EIKMANN *et al.* 2000). The Cu concentration in the soil is only in exceptional cases sufficiently high to cause a risk to humans. The consumption of animal products (e.g. from grazing animals) does not result in any particular risk to health through Cu pollution.

**Effects of Cu on animals**

Cu is essential to animal life. It is added intentionally to fodder (to promote growth). For animals, the difference between essential needs and harmful dose is only small. Thus for ruminants, high Cu exposure causes serious impairment to health. It is known that sheep react particularly sensitively to Cu. For these, the resulting impairment is exacerbated by the high percentage of direct soil ingestion (grazing: cf. Tab. 13). Also, the high sensitivity of sheep to Cu coincides with a deficit of Mo.

Where the Cu trigger value for fodder plant cultivation is exceeded, the nutritional intake of the animals must be analysed prior to other measures. Non-ruminants are much less sensitive to Cu.

**Cu in food plants**

Cu is essential to plant life. However, excessive Cu concentrations in plants can lead to their impairment, and even to their perishing. In the OIS, the clean-up value for Cu was laid down with a view to protecting plants (from loss of productivity), and not to protecting humans (SAEFL 1997a).

**Literatur**

GEORGOPOULOS P.G., ROY A., YONONE-LIOY M. J., OPIEKUN R. E., LIOY P. J., 2001: *«Environmental copper, its dynamics and human exposure issues».* J.Toxicol.Environ.Health, Part B 4, 341–394.

## D Zinc (Zn)

**Effects of Zn on humans**

Zinc is essential to human life and is only toxic at high concentrations. Inhalative exposure and subsequent pulmonary symptoms may occur under special workplace conditions (cf. zinc fever). Acute oral ingestion leads primarily to complaints of the gastro-intestinal tract. Chronic exposure causes changes in the blood count and in kidney function. Harmful effects on the foetus have also been reported (HASSAUER *et al.* 2001). Only in exceptional cases are Zn concentrations in the soil sufficiently high to cause a risk to human health.

**Effects of Zn on animals**

Zn is essential to livestock. Like Cu, it is added intentionally to fodder (to promote growth). Only in exceptional cases are Zn concentrations in the soil sufficiently high to cause a risk to animal health.

**Zn in food plants**

Zn is essential to plant life. However, excessive Zn concentrations in plants can lead to their impairment, and even to their perishing. In the OIS, the clean-up value for Zn was laid down with a view to protecting plants (from loss of productivity) and not to protecting humans (SAEFL 1997a).

## E Polycyclic aromatic hydrocarbons (PAH)

Several hundred PAH compounds are known. They arise primarily during incomplete combustion. For analytical reasons, the OIS regulates only the sum of the 16 PAH indicator substances of the EPA (cf. Priority Pollutants List). In it, benzo(a)pyrene is applied as a representative substance (toxic effects on humans well researched). In risk assessment, the effects of individual PAH compounds on humans are determined using an equivalent benzo(a)pyrene toxicity (cf. Tab. 30).

Tab. 30: 16 PAH compounds and their toxicity equivalents (cancerogenic effect).

| | | | | | |
|---|---|---|---|---|---|
| – benzo(a)pyrene | <u>1</u> | – anthracene | 0.01 | – fluoranthene | 0.001 |
| – dibenzo(a,h)anthracene | 1 | – benzo(ghi)perylene | 0.01 | – fluorene | 0.001 |
| – benzo(a)anthracene | 0.1 | – chrysene | 0.01 | – naphthalene | 0.001 |
| – benzo(b)fluoranthene | 0.1 | – acenaphthene | 0.001 | – phenanthrene | 0.001 |
| – benzo(k)fluoranthene | 0.1 | – acenaphthylene | 0.001 | – pyrene | 0.001 |
| – indeno(1,2,3-cd)pyrene | 0.1 | | | | |

Source: NISBET and LAGOY (1992)

**Effects of PAH on humans**

Chronic human exposure to PAH increases the probability of cancer diseases (skin and lung cancer). Inhalative and oral soil ingestion, and smoking and grilling of meat products and their subsequent consumption, represent typical examples of health risks due to PAH.

**Effects of PAH on animals**

The accumulation of PAH in fodder plants (e.g. grass) is very low. Animals suffer only slight exposure as a result of direct oral soil ingestion or through soiling of fodder. Present knowledge indicates that high PAH concentrations in soils do not represent a health risk to animals. PAH accumulates only to a small extent in animal products.

**PAH in food plants**

The various PAH compounds differ significantly in their characteristics. Their accumulation in plants therefore depends on the particular substance concerned. The ratio of plant content to total content in the soil varies from 0.01:1–10:1 depending on the particular substance and the food plant. Where the exposure is due to creosote (e.g. in former gasworks), this substance facilitates solubility, thereby increasing the transfer to the plants.

An excellent summary of the status of knowledge on soil-to-plant transfer is given in DELSCHEN *et al.* (1999). The authors state that a systemic uptake of PAH via the roots cannot usually be established, particularly in the case of the high-molecular PAH, which are particularly important in human toxicology, e.g. benzo(a)pyrene and dibenzo(a,h)anthracene. In distinction, an uptake can take place through adhesion of polluted soil particles to the plants and subsequent direct transfer to the plant cuticula. This occurs particularly with leaf vegetables growing close to he ground, and is affected significantly by climatic factors (frequency and intensity of soil impingement, i.e. impact of soil particles on the leaves). Owing to this effect, it is not possible to obtain a reliable estimate of the PAH content in plants based solely on the results of soil analyses.

The soil–to–plant transfer of PAH can to a large extent be prevented by covering the polluted soil with mulch. Studies carried out by DELSCHEN *et al.* (1999) indicate that recommendations on husbandry (selection of plant species, sand cover, mulching) *«should provide sufficient protection up to soil concentrations of the order of 15 mg/kg referred to benzo(a)pyrene»* (quote). This is the case for the entire range between the trigger and clean-up values specified in the OIS (trigger range). Particularly in urban areas, a comprehensive assessment of the possible risk from PAH in food plants also requires an assessment to be made of the uptake via the air and of the soil–to–plant transfer (cf. SCHEFFER & SCHACHTSCHABEL 2002, p. 402).

The assessment of PAH in food plants is made based on the maximum content specified in the FIV. Here, values for benzo(a)pyrene are given, and these can be used as toxicity equivalents (cf. Tab. 30) for other PAH compounds

**Literature**

SAEFL, 1998: *«Richt-, Prüf- und Sanierungswerte für organische Schadstoffe im Boden – Fallbeispiel PAK».* Environmental Materials, no. 96, 111 pp., Berne.

DELSCHEN T., HEMBROC-HEGER A., LEISNER-SAABER J., SOPCZAK D., 1999: *«Verhalten von PAK im System Boden/Pflanze»*. Umweltwissenschaften und Schadstoffforschung, 11, 79–87.

LANDESANSTALT FÜR UMWELTSCHUTZ BADEN-WÜRTTEMBERG (ED.), 1997b: *«Stoffbericht – Polyzyklische aromatische Kohlenwasserstoffe (PAK)».* Texte und Berichte zur Altlastenbearbeitung, 34/97, 249 pp.

## F Polychlorinated biphenyls (PCB)

Polychlorinated biphenyls (PCB) are a group of 209 organic aromatic chlorine compounds. Their manufacture commenced in 1930, and they served up to the 1980s, for example, as hydraulic fluids, industrial greases, heat transfer media and dielectrics. Their manufacture and use has been prohibited in Switzerland since 1986. Owing to their fat solubility, PCB accumulate mainly in the fatty tissues of organisms. This effect is amplified along the food chain by biomagnification. In the OIS, for analytical reasons only the sum of the 7 PCB congeners according to the IRMM is used (IUPAC nos. 28, 52, 101, 118, 138, 153, 180).

**Effects of PCB on humans**

PCB accumulates in the fatty tissues of humans. Where pregnant women are subject to increased exposure via foodstuffs, curtailed pregnancies, reduced weight at birth, teratogenicity, retarded development and impairment of the nervous system may occur. Furthermore, the immune system may be impaired. There are also indications of cancerogenic effects of PCB.

**Effects of PCB on animals**

Animals are exposed to PCB both by direct soil ingestion and by soiling of their fodder. However, the accumulation of PCB in fodder plants is of secondary importance. The harmful effects on animals are comparable to those on humans.

**PCB in food plants**

PCB is taken up by plants through the roots. However, very little accumulation takes place. Plants having large underground storage organs (e.g. carrots, potatoes, scorzonera) contain more PCB than plants with above-ground organs.

The assessment of PCB in food plants is based on the maximum content specified in the FIV. Contrary to the trigger and clean-up values specified in the OIS, these apply to the total PCB content. The total content is determined to a first approximation using the following formula:

- Sum of the congeners nos. 28, 52, 101, 138, 153, 180 multiplied by 4.3.

**Literature**

LANDESANSTALT FÜR UMWELTSCHUTZ BADEN-WÜRTTEMBERG (ed.), 1997a: Stoffbericht *«Polychlorierte Biphenyle (PCB)».* Texte und Berichte zur Altlastenbearbeitung, 16/95, 121 pp.

## G Dioxins and furans (PCDD/F)

PCDD/F originate mainly in combustion processes in the presence of chlorine compounds. There are a total of 210 dioxin and furan compounds and these differ substantially in their toxicity. Due to their toxic properties of these only 17 individual compounds are biologically important (typical bond of Cl atoms at positions 2,3,7 and 8). The PCDD/F content is therefore given in toxicity equivalents (I-TEQ/kg). Owing to their fat solubility, PCDD/F accumulate particularly in the fatty tissues of organisms. An amplification of this effect occurs along the food chain (biomagnification).

**Effect of PCDD/F on humans**

Human exposure to PCDD/F occurs to 95% via food (such as milk, meat and fish products containing fats). Milk is classified as unsuitable for consumption when the fat content exceeds 5 ng I-TEQ/kg. Extremely high exposure can cause chlorine acne, hormonal dysfunction and higher probability of contracting cancer. For low exposure, no consequences on health have till now been reported. For the purposes of human protection, the criteria given in Tab. 31 can be applied.

Tab. 31: Exposure range for dioxins and furans for humans (WHO 1998, FIEDLER 2003).

| **Exposure range** [pg I-TEQ/kg body weight] | **Assessment** |
|---|---|
| <1 | Health impairment can be excluded with high probability (preventive limit). |
| 1–4 | Under lifelong exposure, health impairment need not at present be assumed, but adequate confidence does not yet exist in this regard (alarm value). |
| >4 | With long-term daily ingestion, measures must be taken to reduce the dioxin and furan concentrations to below 4 pg I-TEQ/kg body weight. |

**Effects of PCDD/F on animals**

Animals react more sensitively to PCDD/F than humans. The substances are mainly ingested with food. Food plants are mainly contaminated through atmospheric deposition. With animals, for whom oral soil ingestion represents a substantial portion of their total intake (cf. Tab. 13), soil pollution contributes to total exposure. Dairy cows accumulate PCDD/F in milk, and poultry in the fat of their eggs.

**PCDD/F in food plants**

The PCDD/F exposure of plants arises mainly from atmospheric deposition. Owing to their large leaf area, leaf vegetables are particularly affected. To a lesser extent, PCDD/F are also taken up by subsoil plant components. These accumulate mainly in the outer cell layers of the roots. By peeling, the exposure due to consumption of root vegetables can be substantially lowered. A transfer from the roots to the stem and the leaves scarcely occurs, except with pumpkins and courgettes. The ratio of plant content to soil content lies between 0.01 and 0.1. The FIV does not specify maximum values for PCDD/F in food plants.

**Literature**

SAEFL, 1997b: *«Dioxine und Furane – Standortbestimmung, Beurteilungsgrundlagen, Massnahmen».* Environmental Series no. 290, 127 pp., Berne.

FIEDLER H., 2003: *«Dioxins and Furans (PCDD/PCDF)».* Handbook of Environmental Chemistry, vol. 30, 123–201.

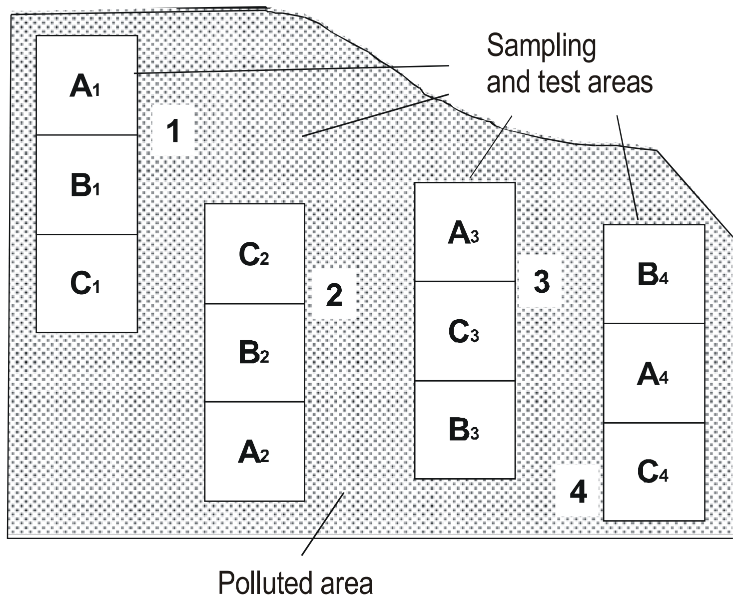
# Annex 3

## Test cultivation

**Sampling and/or test plots**

Test plots should be designated in the polluted area (cf. Fig. 7). For statistical reasons, at least four plots should be selected. To ensure adequate representation of the polluted area, plants having different accumulation properties should be taken or planted on each of the plots, and samples of these evaluated.

Fig. 7: Sampling and test plots for three plant species A, B and C.




**Seed and tending for test cultivation**

To ensure comparability of the results of test cultivation, attention should be paid to consistency of the basic materials (seeds, seedlings) for each species. Sowing or planting are performed using the usual methods in agriculture or horticulture. During cultivation, sufficient nutrients and water should be provided to avoid stress.

**Sampling**

For each sampling or test plot, four (to six) examples of each plant species should be taken and combined to provide three samples per species as follows: mixed samples from $A_1$–$A_4$, mixed samples from $B_1$–$B_4$ and mixed samples from $C_1$–$C_4$. Harvesting is performed using customary horticultural methods. With food plants, non-edible plant components and soil pollution should be removed as far as possible on site.

**Literature**


SAEFL, 1996: *«Sols pollués – métaux lourds et plantes bioindicatrices».* Environmental Materials no. 58, 245 pp., Berne.

# Annex 4

## Impact evaluation for fodder plant cultivation based on threshold values

A threshold value for a trace element is defined as that value that must not be exceeded. Where exceeded, departures from normal animal metabolism can occur, or an animal product will not comply with the hygienic requirements for foodstuffs. A distinction is made between the lower threshold (tolerance threshold) and the upper threshold (toxic threshold) values (KIRCHGESSNER 1997).

Tab. 32: Lower and upper threshold values in feedstuffs for the assessment of the total pollutant exposure of livestock.

| Livestock | Pb [mg/kg dm] | Cd [mg/kg dm] | Cu [mg/kg dm] | Zn [mg/kg dm] | PCB [mg/kg dm] |
|---|---|---|---|---|---|
| Dairy cow | 25–30 | 0.5–30 | 30–100 | 250–500 | 0.1–3 |
| Cattle | – | | 30–100 | 150–500 | |
| Sheep | 15–30 | | 10–25 | 150–500 | |
| Pig | 15–30 | | 150–500 | 100–2000 | |
| Horse | – | | 150–500 | – | |
| Poultry | – | | 300–500 | – | |

Data taken from: KESSLER (1993), HAPKE (1988), NRC (1980), KIRCHGESSNER (1997), FAC (1990).

**Impact analysis**

Contrary to the maximum content specified in the FMBV, the threshold values refer to the total fodder consumed by livestock. Thus the total exposure of the livestock concerned must be calculated. Firstly, the exposure due to the pollutant for each type of fodder is calculated in the same way as in Chap. 5.2.1. Contrary to Chap. 5.2.1, however, the exposure is calculated for all fodder consumed by the livestock concerned as follows:

$$B_i = d_i * c_{total\ content,\ soil} + c_{fodder\ plant} \qquad (A4.1)$$

$B_i$ *Contamination of fodder plant i [mg/kg];*

$c_{total\ content,\ soil}$ *Pollutant content of soil [mg/kg dm], sampling depth 0–5 cm, for soiling of deeper-growing plants (harvested material): 0–20 cm;*

$c_{fodder\ plant}$ *Pollutant content of fodder plant [mg/kg dm];*

$d_i$ *Percentage of direct oral soil ingestion/soiling of fodder plant i (cf. Tab. 13).*

**Total exposure from all fodder plants**

For fodder not originating from polluted areas, average values may be applied (e.g. IPE 1994; cf. Tab. 19). Finally, the total exposure of the livestock is calculated:

$$B_{total} = \sum g_i * B_i \qquad (A4.2)$$

$B_{total}$ *Total contamination of fodder for livestock category [mg/kg];*

$g_i$ *Percentage of fodder plant i in total fodder ration; maximum percentage of individual fodder plants in total fodder (cf. Tab. 13).*

**Impact assessment**

When applying threshold values, the assignment of risk categories is performed according to the criteria in Tab. 33. This must be done for each livestock category and pollutant.

Tab. 33: Risk categories for fodder plant cultivation using threshold values.

| **Total exposure** ($B_{total}$ from Equation A4.2) | **Risk category** |
|---|---|
| Lower threshold value not exceeded | No risk |
| Lower threshold value exceeded | Definite risk possible |
| Upper threshold value exceeded | Definite risk |

# Annex 5

## Uncertainty in comparing measured results with maximum values[10]

### 1 Basic considerations

All measured values are subject to measurement uncertainty. Normally, the measurement uncertainty is specified in terms of the 95% confidence interval of the true value (EURACHEM 1995).

In comparing a measured value to a maximum value, certain conditions must be observed. The content of a sample will only lie above a maximum value with a statistical probability of 95% if the entire confidence interval (for one-sided test) of the measured value lies above the maximum value. Likewise, the maximum value is only exceeded if the entire confidence interval (for one-sided test) of the measured value lies below the maximum value.

It is assumed in the following that the inhomogeneity of the samples is less than the measurement uncertainty due to the measurement procedure.

### 2 Analytical procedure

The measurement uncertainty depends on the precision of the measurement procedure. The precision may be stated as a function of the two variables «comparability R», and «repeatability r». R and r may be calculated from the values of standard deviation for comparability and repeatability, respectively, as follows:

***Comparability:*** $R = 2.8 * s_R$ (A5.1)

*$s_R$: Standard deviation for comparability.*

***Repeatability:*** $r = 2.8 * s_r$ (A5.2)

*$s_r$ : Standard deviation for repeatability.*

Using R and r, the critical difference from the maximum value at the 95% confidence level can be calculated as follows (BAG 1989):

$$D_{95}\,(\bar{x} - H) = [0.84/2^{1/2}] * [R^2 - r^2 * (n-1)/n)]^{1/2} \qquad \text{(A5.3)}$$

*$H$ = maximum value;*

*$\bar{x}$ = average value (determined in the laboratory);*

*$n$ = number of data determined for the analyte.*

Only if the average value lies above the sum of maximum value and critical difference is the maximum value exceeded with a probability of 95%. This method requires R and r to be determined analytically in an inter-laboratory test, together with multiple determinations of (the average value of) the analyte.

---

10 Author of Annex 5: Dr. Claudius Gemperle, Kantonales Laboratorium Aargau, Aarau.

## 3 Assessment using empirical values

In place of precise determination of R and r in an inter-laboratory test, estimated values can be used.

The estimate of $s_R$ according to Horwitz:

$$s_R = 0.02 * C^{0.85} \qquad (A5.4)$$

*C = Massenverhältnis (HORWITZ 2003).*

and the assumption that

$$s_r = s_R / 2 \qquad (A5.5)$$

are generally accepted as reasonable.

The relative standard deviation for comparability, $RSD_R$, may be determined from Equation (A5.6):

$$RSD_R\ (\%) = 2 * C^{-0.15}\ [= 2^{(1-0.5 \log C)}] \qquad (A5.6)$$

Equation (A5.6) shows the dependency of the concentration on $RSD_R$ (see values in Tab. 34). Using Equations (A5.1), (A5.2), (A5.4) and (A5.5), the critical difference between the average value and the maximum value may be obtained from Equation (A5.3).

Tab. 34: Critical difference as a function of concentration.

| **Concentration** C [–] | | **$RSD_R$ (%)** [1)] $2 * C^{-0.15}$ | **Critical difference** average to maximum value (for concentration in %)[2)] |
|---|---|---|---|
| $10^{-1}$ | 100 g/kg | 3 | 4 |
| $10^{-2}$ | 10 g/kg | 4 | 6 |
| $10^{-3}$ | 1 g/kg | 6 | 9 |
| $10^{-4}$ | 100 mg/kg | 8 | 12 |
| $10^{-5}$ | 10 mg/kg | 11 | 17 |
| $10^{-6}$ | 1 mg/kg | 16 | 24 |
| $10^{-7}$ | 0.1 mg/kg | 23 | 34 |
| $10^{-8}$ | 10 µg/kg | 32 | 48 |
| $10^{-9}$ | 1 µg/kg | 45 | 68 |

1) Relative $s_R$ = relative standard deviation for comparability;
2) $D_{95}(\bar{x}–H)$ based on concentration (in %) for n = 3.

Many analysts consider that the critical difference calculated according to HORWITZ (2003) leads to excessively high measurement uncertainty. It is quite possible that in some cases the measurement uncertainty could be lower.

**Literature**


EURACHEM, 1995: *«Quantifying Uncertainty in Analytical Measurement».* ISBN 0 948926 08 2, 87 pp., London.

BAG, 1989: *«Schweizerisches Lebensmittelbuch».* Chapter 60B/annex 4, paragraph 4.

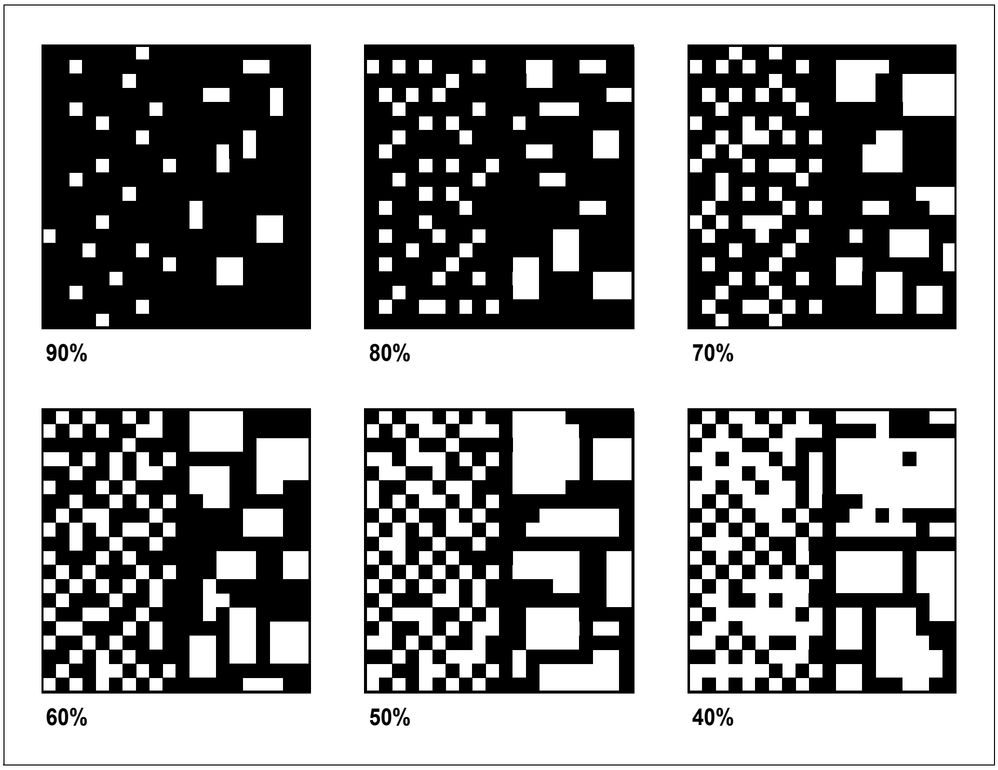
HORWITZ W., 2003: *«The certainty of uncertainty».* J.Assoc.Offic.Anal.Chemists (AOAC) International, 86, no. 1, 109–111.

# Annex 6

## Comparative tables for percentage of soil cover

The following comparative tables can be used to estimate the percentage of soil cover, i.e. the area of soil not directly accessible owing to vegetation cover.

Fig. 8: Comparative tables to estimate the percentage of soil cover.



# Annex 7

## Monitoring form for uses with possible direct soil ingestion

### 1 Identification

**11 Project**

Project description: ........................................ ........................................................ Project no.: ....................................

Monitoring person: ..............................................................................................................................................

**12 Location**

Location, municipality: ................................ ........................................................ Canton: .........................................

Field name: .................................................. ........................................................ Land register no.: ..........................

Coordinates: ................................................ ........................................................ National map no.: .........................

**13 Contacts**

Landowner: ....................................................................................................................................................

Land user: ......................................................................................................................................................

Others concerned: ..........................................................................................................................................

### 2 Situation of the polluted area

**21 Sketch**

**22 Percentage areas**

Polluted area (m²): ........................................ ........................................................ Total cultivated area (m²): ...............

**23 Documentation**

❑ Photographs ❑ Plans

### 3 Use

**31 Use**

❑ Playing area (multiple activities)
- ❑ Kindergarten
- ❑ School
- ❑ Playground
- ❑ Sports ground
- ❑ Park
- ❑ Adventure playground
- ❑ Others: ................................................

❑ Home gardens and allotments
- ❑ Home garden
- ❑ Allotment
- ❑ Others: ................................
................................................
................................................
................................................
................................................

❑ Other uses
- ❑ Industrial wasteland
- ❑ Agriculture
- ❑ Horticulture
- ❑ Forest
- ❑ Others: ................................
................................................
................................................

| 32 Ownership | | |
|---|---|---|
| ❑ Private property<br>❑ In private use (e.g. allotment) | ❑ Public area<br>❑ In public use (e.g. park) | |
| **33 Users** | | |
| Users (multiple activities):<br>❑ Toddlers (up to 3 years)<br>❑ Small children (4–6 years)<br>❑ Children (7–11 years)<br>❑ Youths (12–16 years)<br>❑ Adults (from 17 years<br>Used mainly by: ...................................................... | ❑ Specific users<br><br>❑ Single persons (1–5)<br>❑ Small numbers (5–50)<br>❑ Large numbers (over 50) | ❑ Unspecific users |
| **34 Frequency of use** | | |
| Frequency of use: | ❑ Over once per week<br>❑ Once per week<br>❑ Less than once per week | |
| **35 Future use** | | |
| | | |
| **36 Additional information on use** | | |
| | | |

## 4 Access to area

| 41 Access | | |
|---|---|---|
| ❑ Freely accessible<br>❑ unrestricted access<br>❑ Access prohibited | ❑ Natural barriers<br>❑ Protective mound<br>❑ Ditch<br>❑ Others: …………………... | ❑ Artificial barriers<br>❑ Fence, height: ...................<br>❑ Wall, height: .....................<br>❑ Others: ............................. |
| **42 Additional information on access** | | |
| | | |

## 5 Vegetation

| 51 Vegetation | | |
|---|---|---|
| ❑ Artificial …………………………….. | ❑ Natural …………………………. | |
| **52 Vegetation** | | |
| ❑ Leaf cover<br>❑ Natural meadow<br>❑ Lawn<br>❑ Forest<br>❑ Ruderal<br>❑ Others: ............................................................ | ❑ Shrub cover<br>❑ Thorny<br>❑ Non-thorny | ❑ Tree cover |
| **53 Percentage of total vegetation cover:**<br>**What percentage of the soil is not directly accessible?** (cf. comparative table in Annex 6) | | |
| Percentage cover (%): ........................................... | | |
| **54 Possible changes in vegetation cover** | | |
| | | |

## 6 Date and signature

| 61 Date and signature | |
|---|---|
| Date: ........................................................... ........................... | Signature: ..................................................................... |

# Annex 8 Reference values according to EIKMANN & KLOKE (1993)

**Soil values:** **BW I**: Basic value (background value), comparable to the **guide value** (OIS);
**BW II:** Trigger value (target value for clean-up), comparable to **trigger value** (OIS);
**BW III:** Intervention value, comparable to **clean-up value** (OIS).

| Use category | | Soil value | Inorganic pollutants | | | | | | | | | | | | | | | | | | | | | | | | Organic pollutants | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | As | B | Ba | Be | Br | Cd | Co | Cr | Cu | F*** | Ga | Hg | Mo | Ni | Pb | Sb | Se | Sn | Tl | U | V | Zr | Zn | $CN_{tot}$ | Benzo(a)-pyrene | PCB | PCDD/PCDF [ng TEQ/kg] |
| Subject of protection: humans | Multifunctional | BW I | 20 | 25 | 100 | 1 | 10 | – | 30 | – | – | – | 10 | – | – | – | – | 1 | 1 | 50 | 0.5 | 2 | 50 | 300 | – | 5 | – | – | – |
| | Children's playground | BW II | 20 | 25 | 100 | 1 | 10 | – | 30 | * | * | *** | 10 | * | * | * | – | 2 | 5 | 50 | 0.5 | 2 | 50 | 300 | – | 5 | – | – | – |
| | | BW III | 50 | 125 | 500 | 5 | 50 | – | 150 | 250 | – | *** | 50 | 10 | 25 | 200 | – | 10 | 20 | 250 | 10 | 10 | 200 | 1500 | – | 50 | – | – | – |
| | Home and other small gardens | BW II | 40 | 50 | 200 | 2 | 20 | – | 100 | 100 | * | *** | 20 | 2 | 10 | 80 | – | 4 | 5 | 100 | 2 | 5 | 100 | 500 | – | 20 | – | – | – |
| | | BW III | 80 | 250 | 1000 | 5 | 100 | – | 400 | 350 | – | 2500 | 100 | 20 | 50 | 200 | – | 10 | 10 | 500 | 20 | 20 | 400 | 2000 | – | 400 | – | – | – |
| Other subjects of protection | Multifunctional | BW I | 20 | 25 | 100 | 1 | 10 | – | 50 | – | – | – | 10 | – | – | – | – | 1 | 1 | 50 | 0.5 | 5 | 50 | 300 | – | 5 | – | – | – |
| | Agricultural areas, fruit growing and horticulture | BW II | 40 | 50 | 300 | 2 | 30 | – | 200 | 200 | – | 1000 | 40 | 10 | 20 | 100 | – | 5 | 5 | 100 | 2 | 10 | 100 | 500 | 300 | – | – | – | – |
| | | BW III | ** | 250 | 1500 | 5 | 150 | – | 1000 | 500 | – | 5000 | 200 | 50 | 100 | 200 | – | 25 | 10 | 500 | 10 | 50 | 400 | 2000 | – | – | n.a. | – | – |

[Values in mg/kg soil where not otherwise specified].

n.a. = Not available.

TEQ = Toxicity equivalent, cf. Annex 2G.

– = Here, the regulatory value specified in the OIS to be used.

* = To obtain the trigger value equivalent, the guide value specified in OIS should be doubled, since the BW II specified by EIKMANN & KLOKE (1993) is lower than or equal to the OIS value.

** = To obtain the clean-up value equivalent, the BW II value should be doubled, since the BW III value specified by EIKMANN & KLOKE (1993) of 50 mg/kg is only slightly higher than the BW II value.

*** = For fluorine, the BW II and BW III values given by EIKMANN & KLOKE (1993) lie partly below and partly (a little) above the guide value specified in OIS. Particularly for fluorine, the influence of different extraction methods and assessment criteria should be observed. In cases of doubt, a detailed study is recommended.

**Notes:** The sampling depths and extraction methods specified in the OIS differ from those assumed by EIKMANN & KLOKE (1993), e.g. solution in 2M $HNO_3$ in the OIS as opposed to aqua regia in Germany). In certain casesthe result can differ and must be taken into account. The use categories specified here are those for which regulatory values are specified in the OIS. Further use categories are to be found in EIKMANN & KLOKE (1993). Information on the extraction and measurement procedures used in Germany may be found in the German Bundes-Bodenschutz- und Altlastenverordnung (BBodSchV), and in: ROSENKRANZ D., BACHMANN G., KÖNIG W., EINSELE G. (ed.), updatable handbook «Bodenschutz», *code no. 8005,* Erich Schmidt Verlag, Berlin.

**Literature:** EIKMANN T., KLOKE A. 1993: *Nutzung- und schutzgutbezogene Orientierungswerte für (Schad-)Stoffe in Böden.* In: ROSENKRANZ D., BACHMANN G., KÖNIG W., EINSELE G. (ed.), updatable handbook «Bodenschutz», *code no. 3590,* Erich Schmidt Verlag, Berlin.

# Annex 9

## Calibration of expert systems

### A Expert system for food plant cultivation

**Available data**

To calibrate the expert system food plant cultivation, the TRANSFER database of the German Agency for the Environment in Dessau (UBA) was used.[11] This contains 317'000 data pairs of pollutant concentrations in the soil and plants, together with data on soil properties. Data were available on the following pollutants (inorganic only):

Ag, As, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Sn, Tl, U, V, Zn

Only a part of the total TRANSFER data compatible with OIS specifications and with Swiss foodstuffs legislation was selected for calibration purposes using the following criteria:

1. *Plant species:* species classified as food plants in the FIV;
2. *Plant pretreatment:* washed, but not cooked;
3. *Soil extraction:* in aqua regia;
4. *Soil pH:* between 4.25 and 7.75 ($CaCl_2$);
5. *Soil sampling depths:* 0–20, 0–25 and 0–30 cm, and pot tests. This is the only point at which the procedure departs from the OIS criteria (sampling depth 20 cm). This relaxation of the OIS criteria is probably justified (fairly effective mixing of soil in arable areas and in gardens, and in pot tests). This was necessary to provide an adequate data basis.

This procedure resulted in 20 187 data pairs suitable for calibrating the expert system food plant cultivation. The distribution of individual elements in the subset is shown in Tab. 35.

The calibration is based on limiting pollutant concentrations in foodstuffs. These represent a measure of the human toxicity of substances. For food plants, the FIV only specifies maximum values for the heavy metals Cd, Pb and Tl. Internationally, maximum values in food plants have till now only been specified for Cd and Pb (BERG & LICHT 2002). The calibration procedure for these three heavy metals is explained in the following for Cd. The same procedure was used for Pb and Tl.

**Cd, Pb and Tl**

In performing the calibration, it was not possible to standardise all of the contributing factors, i.e. it was not possible to perform a separate correlation for every possible combination of soil characteristics and plant species.

[11] The TRANSFER database was made available with the kind permission of the Federal Agency for the Environment (UBA) in Dessau, and the regional German governments (Länder), to whom our thanks are due.

Tab. 35: Calibration of the expert system food plant cultivation: number of usable data pairs.

| Elements | Number of usable data pairs |
|---|---|
| As | 560 |
| Cd | 4992 |
| Cr | 1483 |
| Cu | 544 |
| Hg | 1255 |
| Ni | 2524 |
| Pb | 4366 |
| Tl | 149 |
| Zn | 4314 |

The reasons for this are as follows: (a) insufficient data were available to cover all possible combinations of parameters; (b) to cover all combinations of parameters, up to 90 individual correlations would have had to be calculated for each pollutant and subsequently weighted; (c) the simple basic structure of the calibration system would have become more complex. Thus for each individual substance, calibration was performed using a ***single*** combination of parameters selected so as to cover the greatest possible number of data pairs, and thereby represent a typical case.

Tab. 36: Combinations of parameters used for calibrating Cd, Pb and Tl.

| Element | pH value (CaCl2) | Organic substance content [%] | Clay content [%] | Plant species factor | Number of value pairs |
|---|---|---|---|---|---|
| Cd | 5.75–6.75 | <8 | no restrictions | 2 | 533 |
| Pb | 6.75–7.75 | 2–15 | <25 | 2 | 2061 |
| Tl | 6.25–7.75 | no restrictions | <45 | 2 | 116 |

For the above combinations of parameters, the concentrations of individual pollutants in soils and plants were displayed graphically as shown in Fig. 9. This shows the results for Cd. The FIV maximum value for Cd amounts in this case to 0.2 mg/kg fresh weight. For plant species for which die FIV specifies other values, the results were modified accordingly.

It is apparent from Fig. 9 that the scatter of the data is large, this despite comparable soil and plant characteristics. Logarithmic axes were intentionally avoided, as this would merely have masked the scatter. Plant concentrations lying significantly above the FIV limit value occurred not only above, but also below, soil concentrations of 2 mg/kg (trigger value).

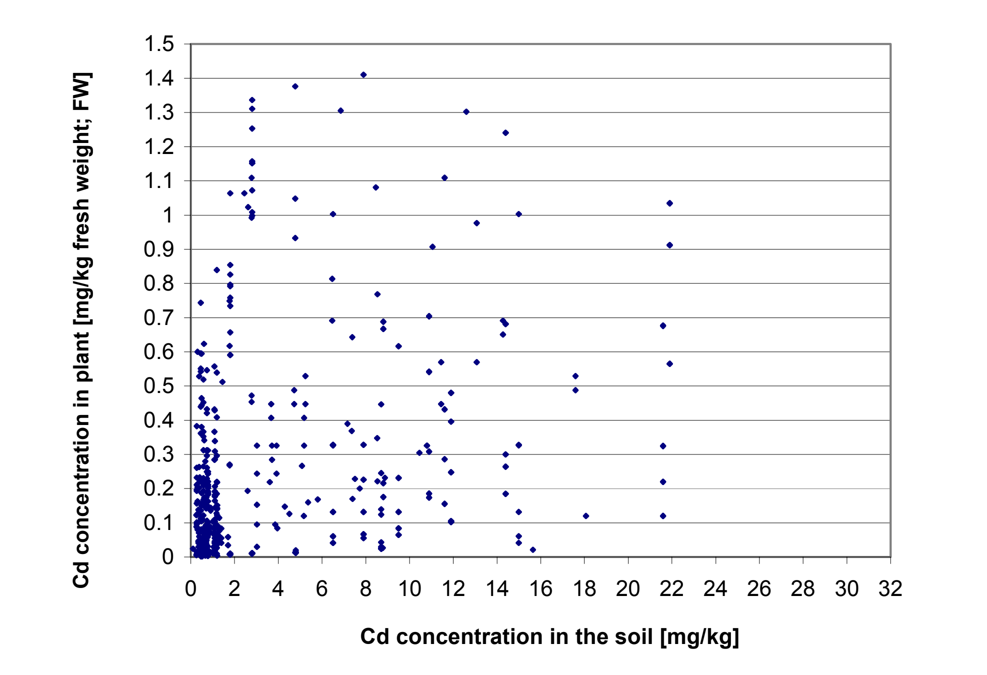
However, for the majority of data pairs, the plant concentration lies below the FIV limit value up to quite high soil concentrations, as shown in Fig. 10. This displays the medians of the plant concentrations calculated in steps of 0.1 mg/kg soil concentration. The straight line shows the linear correlation of the median values and intersects the FIV limit value for Cd at a soil concentration of approx. 5 mg/kg.

For Cd, the expert system was calibrated for the above combination of parameters to assign the category *«definite risk»* at soil concentrations above 5 mg/kg (risk score of at least 5). This was performed simply by adjusting the correction factor T to 0.5 points. The term *«definite risk»* thereby assumes the following meaning:

***The risk arising from a soil pollutant is designated as «definite» if the probability that food plants produced on the soil will exceed the FIV limit value is at least 50%.***

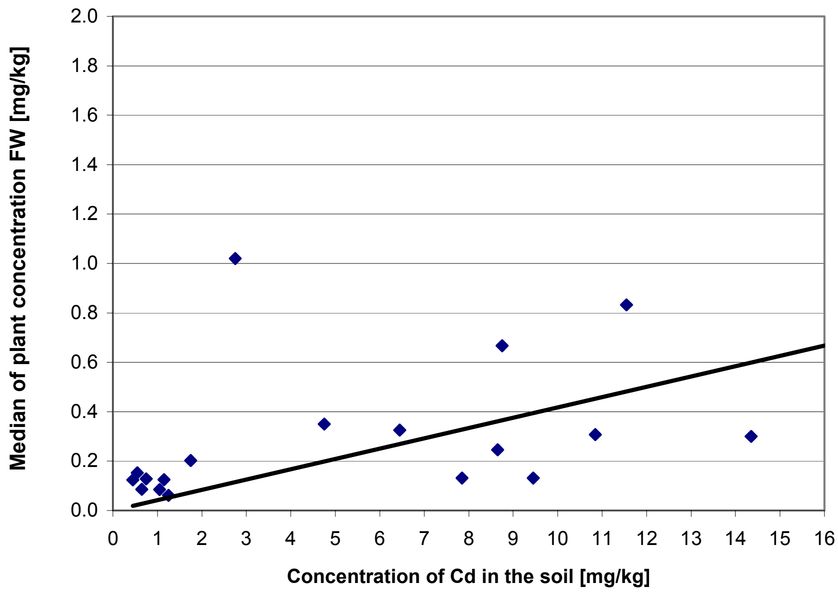
In cases where the expert system food plant cultivation leads to assignment of the category *«definite risk possible»,* the FIV limit value for food plants is quite frequently exceeded. In these cases, it is therefore justifiable and necessary to make official recommendations to the users.

Fig. 9: Cd concentrations in soils and plants. Characteristic factors: plants with high Cd uptake (plant species factor = 2, pH 5.75–6.75, organic substance ≤8 %).




The result of the calibration was verified for the total number of usable data pairs used in the calibration (4992 data pairs for Cd). To do so, the hit ratio and the so-called diagnosticity were determined for each pair. For the data pairs for which the category *«definite risk»* was assigned by the expert system, the hit ratio designates the number of data for which the FIV limit value is actually exceeded in the food plants.

Fig. 10: Median values of Cd content in plants at intervals of soil content of 0.1 mg/kg (0.0–0.1, 0.1–0.2 mg/kg) and their linear correlation. The medians are only displayed where at least nine measurements were present in the interval.




The diagnosticity only refers to data pairs for which the FIV limit value in food plants is exceeded. The diagnosticity is defined as the percentage number of data with concentrations in the soil lying within the trigger range for soil concentrations below the clean-up value. Thus, the diagnosticity signifies the percentage of ‹problematical› cases (exceeding of the FIV limit value in food plants), for which a risk assessment would in fact have to be performed (cf. Tab. 37).

Tab. 37: Hit ratio and diagnosticity for Cd, Pb and Tl.

| **Elements** | **Hit ratio** [%] | **Diagnosticity** [%] |
|---|---|---|
| Cd | 68.7 | 82.6 |
| Pb | 55.2 | 67.7 |
| Tl | 50.0 | 78.6 |

The lower hit ratio for Pb is due to the well-established higher variability of the soil–to–plant transfer in comparison to Cd. For Tl, the data basis is much narrower, with 116 usable data pairs, so the result is subject to larger uncertainties.

As the results for Cd and Pb show, caution should be observed. The difficulty arises from the understandable desire to assess as large a number of pollutants as possible using the simplest possible procedures (see, for example, BÄCHI *et al.* 2004). Even when an excellent data basis is available, as in the case of the two elements mentioned above. Procedures of this type are subject to substantial uncertainty. This is because the soil-plant system is extremely complex and is difficult to describe reliably with such highly simplified parameters.

Expert systems are hardly adequate to assign a (definite) risk from food plants based on soil concentrations alone if:

- the data basis is unreliable;
- no maximum pollutant concentrations in plants have been specified, or
- a substantial percentage of the pollutant content in plants originates from direct atmospheric deposition (particularly with organic micro pollutants).

**Cu and Zn**

In the OIS, the clean-up values for Cu and Zn in gardens were laid down with a view to protecting plants (from loss of yield), and not to protecting humans (SAEFL 1997a). For this reason, the correction factors T for these pollutants were reduced as far as the legislative framework would permit (above the clean-up value, a definite risk must always be assigned). This ensures that the category *«definite risk possible»* is always assigned at a point below the clean-up value. This avoids an illogical abrupt transition from the category *«no definite risk»* to *«definite risk»* when the clean-up value is reached.

**Other inorganic pollutants**

For the other inorganic pollutants, the FIV does not specify maximum concentrations in food plants. Nor have limiting values been specified internationally (BERG & LICHT 2002). In calibrating the expert system, the attempt was made to employ the PTWI values of the FAO/WHO as a basis.

The PTWI values were determined for a broad range of inorganic pollutants (WATSON 2001, REILLY 2002, D'MELLO 2003). In this, the conversion of the tolerable ingestion rates for humans to limiting pollutant values in food plants met with considerable difficulty.

When the attempt is made to apply the assessment procedure for the PTWI values derived for Pb and Cd to other elements, and reference values are calculated for the relevant elements based on the FIV limit values for Pb and Cd, the results are found to be partly unrealistic. Thus, for example, the limit value for Hg in plants calculated in this way was only reached at Hg concentrations in the soil of several hundred mg/kg, i.e. several times higher than the BW III value given by EIKMANN and KLOKE (1993).

Thus for these pollutants, the threshold between the trigger and clean-up values at which a definite risk occurs cannot be uniquely determined. The correction factor T was set to zero to signify undeterminable. In these cases, no category *«definite risk»* is assigned between the trigger and the clean-up values (cf. Tab. 8).

## B Expert system for fodder plant cultivation

To calibrate the expert system fodder plant cultivation, the TRANSFER database of the German Agency for the Environment in Dessau (UBA) was used[12] (cf. Annex 9A).

Only a part of the total TRANSFER data compatible with OIS specifications and with Swiss livestock feedstuffs legislation was selected for calibration purposes using the following criteria:

**Available data**

1. *Plant species:* species classified as food plants in the FMBV;
2. *Plant pretreatment:* unwashed and not pretreated plants or parts of plants;
3. *Soil extraction:* in aqua regia;
4. *Soil pH:* between 4.25 and 7.75 ($CaCl_2$);
5. *Soil sampling depths:* 0–20, 0–25 and 0–30 cm and pot tests. This is the only point at which the procedure departs from the OIS criteria (sampling depth 20 cm). This relaxation of the OIS criteria is probably justified (fairly effective mixing of soil in arable areas and in gardens, and in pot tests). This was necessary to provide an adequate data basis.

This procedure resulted in 8503 data pairs suitable for calibrating the expert system fodder plant cultivation. The distribution of individual elements in the subset is shown in Tab. 38.

Tab. 38: Calibration of the expert system for «fodder plant cultivation»: number of usable data pairs.

| Elements | Number of usable data pairs |
|---|---|
| As | 49 |
| Cd | 1576 |
| Cr | 713 |
| Cu | 1341 |
| Hg | 611 |
| Ni | 1223 |
| Pb | 1503 |
| Tl | 0 |
| Zn | 1487 |

It was concluded from the data for As, Cr, Hg, Ni and Pb that for animals, the pollutant quantities taken up by plants are hardly ever likely to be relevant in comparison to direct soil ingestion.

**Cd, Cu, Zn**

For the elements Cd, Cu and Zn, the expert system fodder plant cultivation was calibrated in the same way as for the expert system food plant cultivation for the

[12] The TRANSFER database was made available with the kind permission of the Federal Agency for the Environment (UBA) in Dessau, and the regional German governments (Länder), to whom our thanks are due.

elements Cd, Pb and Tl (cf. Annex 9A). This applies to cases ***without*** direct oral ingestion or crop soiling. Following that, the data for hit ratio and diagnosticity shown in Tab. 39 were determined (only for the exposure path via root uptake):

Tab. 39: Hit ratio and diagnosticity for Cd, Cu and Zn (only for root uptake).

| **Elements** | **Hit ratio** [%] | **Diagnosticity** [%] |
|---|---|---|
| Cd | 66.9 | 78.4 |
| Cu | 62.2 | 70.9 |
| Zn | 72.8 | 84.3 |

The somewhat larger uncertainties with Cu may be attributed to the narrower data basis (only 89 data pairs were available between the trigger and clean-up values).

The ingestion path via direct oral ingestion and/or crop soiling is independent of the path via root uptake. The uncertainties here lie entirely in the percentage of soil ingested by livestock (factor d, cf. Tab. 13). However, very few data are available on this, and no data are available in the TRANSFER database.

It was not possible to determine the hit ratio and diagnosticity for the expert system fodder plant cultivation. The relatively high percentage of soil ingestion by sheep may seem surprising at first sight. Indications that the percentages according to Tab. 13 are realistic, and may even be exceeded, are given in ABRAHAMS & STEIGMAJER (2003).

**Further information on Cu and Hg**

For Cu, relatively low soil concentrations in fodder plant cultivation lead to the category *major risk* being attributed to sheep. This does not result directly from the expert system, but is caused by the relationship between soil concentration, FMBV maximum concentration, and percentage of soil in the fodder. For a Cu concentration in the soil of >150 mg/kg (trigger value) and a soil ingestion by grazing sheep of 10–15% (dry conditions), the Cu content in fodder from the polluted area ***always*** exceeds the FMBV maximum value of 15 mg/kg for sheep. For Cu, the FMBV only stipulates maximum values for the total fodder of livestock. For this reason, the critical values for animal feedstuffs given by BLUME (1992) have also been quoted to provide reference values for single-component feeds.

Even relatively low Hg concentrations in the soil lead to the category *major risk* occurring in fodder plant cultivation. The reason for this is the same as in the case of Cu. With a Hg concentration in the soil of >10 mg/kg (BW II used as trigger value equivalent), the maximum FMBV value of 0.1 mg/kg is ***always*** exceeded in the livestock fodder from the polluted area at a soiling percentage of 1%. For this reason, Hg pollution of the soil for the use category fodder plant cultivation is regarded as highly problematical. However, this is substantially more seldom than Cu pollution of former vineyard soils.

## C Expert system for uses with possible direct soil ingestion

The expert system uses with possible direct soil ingestion was compared with the analytical UMS (Environment–Humans–Pollutant) model of the German Agency for the Environment (UBA 1998). A calibration of the expert system as such is not possible using this model, because the model itself is not based on measured data but on assumptions. Furthermore, the *«UMS model»* includes a large number of additional parameters, such as relocation of a polluted area outside of a residential area, background exposure and other divisions of age classes. In the *«UMS model»*, the risk is calculated with the aid of so-called «risk-coupled factors», which differ from one element to another, and for which a distinction is made between the categories «toxic» and «cancerogenic».

In making the comparison, the following settings were chosen for the *«UMS model»:*

- *Pollutants:* As, Pb, Cd, Cr, Ni, Hg and benzo(a)pyrene. These pollutants are those of the *«UMS model»* for which EIKMANN & KLOKE (1993) and the OIS recommend standard or regulatory values respectively.
- *Exposure scenarios:* «children's playgrounds» and «gardens».
- *Distance from residential areas:* <500 m.
- For the three UMS criteria «soil ingestion rate», «physiological variables» (e.g. resorbed fractions) and «substance-specific data», the calculated data of the *«UMS model»* were accepted.

As it is not possible in the present context to go into all combinations of cases, the comparison is illustrated for a particular example. For a soil pollution of 1.25 times the trigger value (or the BW II value), ground cover of 80% and a frequency of use of 1–2 times per week, the values for the use category «gardens» are shown in Tab. 40.

Tab. 40: Comparison between the expert system (ES) for uses with possible direct soil ingestion and the *«UMS model»* for a specific case.

| Pollutants \ Age | ES | UMS | ES | UMS | ES | UMS | ES | UMS |
|---|---|---|---|---|---|---|---|---|
| | 2 years | | 5 years | | 9 years | | 14 years and older | |
| As | ++ | ++ | ++ | ++ | + | ++ | + | ++ |
| Pb | ++ | + | + | – | – | – | – | – |
| Cd | ++ | ++ | ++ | ++ | + | ++ | + | ++ |
| Cr | ++ | ++ | + | ++ | – | ++ | – | ++ |
| Ni | ++ | + | ++ | + | + | + | + | + |
| Hg | ++ | – | + | – | – | – | – | – |
| Benzo(a)pyrene | ++ | ++ | + | ++ | – | ++ | – | ++ |

++ = *«definite risk»* or «prone to be a risk»
+ = *«definite risk possible»* or «area of increasing incidence of concern»
– = *«no definite risk»* or «negligible risk»

The greatest deviations between the expert system (ES) and the *«UMS model»* occur for Cr, Hg and benzo(a)pyrene. In the *«UMS model»,* inorganic Hg alone was considered. Thus the highly toxic organic Hg compounds are excluded. For As, Cr and benzo(a)pyrene, the *«UMS model»* results in very high risk values for cancerogenicity. Also, the same risk category results for adults as for toddlers. These additional differences also point to the difficulty of comparing the two approaches.

# Annex 10

## Tables for guide, trigger and clean-up values

**(cf. Annexes 1 and 2 OIS; SR814.12)**

**Annex 1 OIS**

## 1 Inorganic pollutants

### 1.1 Guide values

| **Pollutant** | **Concentration** (mg/kg dm for soils up to 15 % humus,mg/dm³ for soils over 15 % humus) | |
|---|---|---|
| | Total concentration | Soluble concentration |
| Chromium (Cr) | 50 | – |
| Nickel (Ni) | 50 | 0.2 |
| Copper (Cu) | 40 | 0.7 |
| Zinc (Zn) | 150 | 0.5 |
| Molybdenum (Mo) | 5 | – |
| Cadmium (Cd) | 0.8 | 0.02 |
| Mercury (Hg) | 0.5 | – |
| Lead (Pb) | 50 | – |
| Fluorine (F) | 700 | 20 |

dm = dry matter

### 1.2 Trigger values

| **Use category** | **Concentration** (mg/kg dm for soils up to 15 % humus,mg/dm³ for soils over 15 % humus) | | | | | | **Sampling depth** (in cm) |
|---|---|---|---|---|---|---|---|
| | Lead (Pb) | | Cadmium (Cd) | | Copper (Cu) | | |
| | t | l | t | l | t | l | |
| Food plant cultivation | 200 | – | 2 | 0.02 | – | – | 0–20 |
| Fodder plant cultivation | 200 | – | 2 | 0.02 | 150 | 0.7 | 0–20 |
| Uses with possible direct[1] soil ingestion | 300 | – | 10 | – | – | – | 0–5 |

dm = dry matter  l = soluble content  t = total content

[1] oral, inhalative, dermal

### 1.3 Clean-up values

| **Use category** | **Concentration** (mg/kg dm for soils up to 15 % humus,mg/dm³ for soils over 15 % humus) | | | | | | | | **Sampling depth** (in cm) |
|---|---|---|---|---|---|---|---|---|---|
| | Lead (Pb) | | Cadmium Cd) | | Copper (Cu) | | Zinc (Zn) | | |
| | t | l | t | l | t | l | t | l | |
| Agriculture and horticulture | 2000 | – | 30 | 0.1 | 1000 | 4 | 2000 | 5 | 0–20 |
| Home gardens and allotments | 1000 | – | 20 | 0.1 | 1000 | 4 | 2000 | | 0–20 |
| Children's playgrounds | 1000 | – | 20 | – | – | – | – | – | 0–5 |

dm = dry matter  l = soluble content  t = total content

Annex 2 OIS

# 2 Organic pollutants

## 2.1 Values for dioxins (PCDD) and furans (PCDF)

| Value | | PCDD/F content [1] (ng I-TEQ/kg dm for soils up to 15 % humus, ng I-TEQ/dm³ for soils over 15 % humus) | Sampling depth (in cm) |
|---|---|---|---|
| Guide value | | 5 | 0–20 |
| Trigger values | Uses with possible direct[2] soil ingestion | 20 | 0–5 |
| | Food plant cultivation | 20 | 0–20 |
| | Fodder plant cultivation | 20 | 0–20 |
| Clean-up values | Children's playgrounds | 100 | 0–5 |
| | Home gardens and allotments | 100 | 0–20 |
| | Agriculture and horticulture | 1000 | 0–20 |

I-TEQ = International toxicity equivalents
TS = dry matter
[1] PCDD/F= Sum of the polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans
[2] oral, inhalative, dermal

## 2.2 Values for polycyclic aromatic hydrocarbons (PAH)

| Value | | PAH[1] (mg/kg dm for soils up to 15 % humus, mg/dm³ for soils over 15 % humus) | | Sampling depth (in cm) |
|---|---|---|---|---|
| | | Sum of the 16 indicator substances | Benzo(a)pyrene | |
| Guide value | | 1 | 0.2 | 0–20 |
| Trigger values | Uses with possible direct[2] soil ingestion | 10 | 1 | 0–5 |
| | Food plant cultivation | 20 | 2 | 0–20 |
| Clean-up values | Children's playgrounds | 100 | 10 | 0–5 |
| | Home gardens and allotments | 100 | 10 | 0–20 |

dm = dry matter
[1] The values apply to the sum of the following 16 PAH indicator substances of the EPA (priority pollutants list): naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno-(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene and benzo(g,h,i)perylene.
[2] oral, inhalative, dermal

## 2.3 Values for polychlorinated biphenyls (PCB)

| Value | | PCB-content [1] (mg/kg dm for soils up to 15 % humus, mg/dm³ for soils over 15 % humus) | Sampling depth (in cm) |
|---|---|---|---|
| Trigger values | Uses with possible direct[2] soil ingestion | 0.1 | 0–5 |
| | Food plant cultivation | 0.2 | 0–20 |
| | Fodder plant cultivation | 0.2 | 0–20 |
| Clean-up values | Children's playgrounds | 1 | 0–5 |
| | Home gardens and allotments | 1 | 0–20 |
| | Agriculture and horticulture | 3 | 0–20 |

dm = dry matter
[1] Sum of the 7 congeners specified by the IRMM (Institute for Reference Materials and Measurements), IUPAC nos. 28, 52, 101, 118, 138, 153, 180
[2] oral, inhalative, dermal

# Index

## 1 Abbreviations

**A horizon**
Topsoil – used in a qualitative sense for the purposes of soil legislation enforcement

**Agroscope FA**
Swiss agricultural research stations (e.g. Swiss Federal Research Station for Agroecology and Agriculture – *Agroscope FAL Reckenholz,* Zurich)

**BAG**
Swiss Agency of Public Health (SAPH), Berne

**B horizon**
Subsoil – used in a qualitative sense for the purposes of soil legislation enforcement

**BW**
Soil values as given by EIKMANN & KLOKE (1993), Berlin

**C horizon**
Substratum – used in a qualitative sense for the purposes of soil legislation enforcement

**DCPS**
Federal Department for Defense, Civil Protection and Sports

**dm**
Dry matter

**DHA**
Federal Department of Home Affairs, Berne

**DEA**
Federal Department of Economic Affairs, Berne

**EU**
European Union

**FAO**
UN Food and Agriculture Organisation

**FIV**
Ordinance on Foreign Substances and Additives
(OFSA; SR 817.021.23)

**FMBV**
Livestock Feedstuff Book Ordinance of DEA (LFBO; SR 916.307.1)

**FW**
Fresh weight

**IRMM**
Institute for Reference Materials and Measurements

**LMV**
Foodstuffs Ordinance (FO; SR 817.02)

**LPE**
Law relating to the Protection of the Environment of 7 October 1983 (SR 814.01)

**OCS**
Ordinance on Contaminated Sites of 26 August 1998 (SR 814.680)

**OIS**
Ordinance relating to Impacts on the Soil of 1 July 1998 (SR 814.12)

**PAH**
Polycyclic aromatic hydrocarbons

**PCB**
Polychlorinated biphenyls

**PCDD/F**
Polychlorinated dibenzo-*p*-dioxins and dibenzofurans («dioxins»)

**PTWI**
Provisional Tolerable Weekly Intake (cf. FAO/WHO, 2003)

**PW**
Trigger values (cf. OIS)

**RW**
Guide values (cf. OIS)

**SAEFL**
Swiss Agency for Environment, Forests and Landscape, Berne

**SACA**
Swiss Agency for Civil Aviation, Berne

**SAT**
Swiss Agency for Traffic, Berne

**SW**
Clean-up values (cf. OIS)

**UBA**
Umweltbundesamt Dessau, Germany

**UMS model**
*«Environment–Humans–Pollutant»* programme of the Agency for the Environment in Dessau (UBA) to determine the risk arising from suspected contaminated sites – on the basis of tolerable pollutant concentrations in human toxicology (19 organic and 8 inorganic substances are considered – as of 1998; cf. SAEFL Environmental Materials no. 176, 1998, *Polluted Soils – Quantitative Analytical Models)*

**WHO**
World Health Organization

# 2 List of figures

# 3 List of tables

# 4 Literature

## Legislation

Federal Law relating to Administrative Procedures of 20 December 1968 (SR 172.021).
Federal Law relating to the Protection of the Environment of 7 October 1983 (LPE; SR 814.01 – amended 21 December 1995).
Federal Law relating to the Army and the Military Administration of 3 February 1995 (Military Law, ML; SR 510.10).
Ordinance relating to Foodstuffs and Articles of Daily Use of 1 March 1995 (LMV; SR 817.02).
Foreign Substances and Additives Ordinance of the DHA of 26 June 1995 (FIV; SR 817.021.23).
Ordinance relating to the Procuction and Placing on the Market of Livestock Feedstuffs of 26 May 1999 (Feedstuffs Ordinance, FMV; SR 916.307).
Ordinance of DEH 10 Juni 1999 relating to the Production and Placing on the Market of Livestock Feedstuffs, Additives for Animal Nutrition and Silage Additives (Livestock Feedstuff Book Ordinance, FMBV; SR 916.307.1).
Ordinance relating to Impacts on the Soil (OIS) of 1 July 1998 (SR 814.12).
Ordinance relating to the Rehabilitation of Contaminated Sites of 26 August 1998 (Contaminated Sites Ordinance, OCS; SR 814.680).
Ordinance on the Reduction of the Risks Related to the Use of Certain Particularly Dangerous Substances, Preparations and Objects of 18 May 2005 (Ordinance on the Reduction of Risks Related to Chemical Products, ORRChem; SR 814.81)
Ordinance relating to the Protection Against Dangerous Substances and Preparations of 18 May 2005 (Chemicals Ordinance, OChem; SR 814.81).

## Further literature

ABRAHAMS P.W., STEIGMAJER J. 2003: *«Soil ingestion by sheep grazing the metal enriched floodplain soils of Mid-Wales».* Environmental Geochemistry and Health, 25, 17–24.
AG BODEN 1994: *«Bodenkundliche Kartieranleitung».* Arbeitsgruppe Boden der Geologischen Landesämter der Bundesrepublik Deutschland, Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.
AGROSCOPE FAL RECKENHOLZ, ANNUAL: *«VBBo-Ringanalysenberichte».* Zurich.
AGROSCOPE FAL RECKENHOLZ 1998: *«Methodenbuch für Boden-, Pflanzen- und Lysimeterwasser-Untersuchungen».* Zurich.
AGROSCOPE FAL RECKENHOLZ 1997: *«Kartieren und Beurteilen von Landwirtschaftsböden».* Zurich.
AGROSCOPE FAL RECKENHOLZ 1996 (amendments 1997–2005): *«Schweiz. Referenzmethoden der Eidg. Landwirtschaftl. Forschungsanstalten».* Zurich.
AGROSCOPE FAL RECKENHOLZ 1990: *«Kriterien zur Beurteilung einiger Schadstoffgehalte von Futter- und Nahrungspflanzen».* Report series no. 8 of the former Eidg. Forschungsanstalt für Agrikulturchemie und Umwelthygiene, Liebefeld-Berne, 156 pp.

AGROSCOPE FAL 1989: *«Methodik zur Bestimmung biologisch relevanter Schwermetallkonzentrationen im Boden im Boden und Überprüfung der Auswirkungen auf Testpflanzen sowie Mikroorganismen in belasteten Gebieten».* Report series no. 2 of the former Eidg. Forschungsanstalt für Agrikulturchemie und Umwelthygiene, 54 pp., Liebefeld-Berne.

AMT FÜR LANDWIRTSCHAFT DES KANTONS BERN, ABTEILUNG UMWELT UND LANDWIRTSCHAFT: *«Bodenbericht 2003».* 51 pp., Zollikofen.

AMT FÜR LANDWIRTSCHAFT DES KANTONS BERN, ABTEILUNG UMWELT UND LANDWIRTSCHAFT 2001: *«Bodenbelastung Scherbenland Witzwil».* 37 pp. – Schlussbericht, Zollikofen.

AMT FÜR UMWELTSCHUTZ DES KANTONS SOLOTHURN 1998: *«Schadstoffbelastung von Hausgärten in der Stadt Olten».* 44 pp., Solothurn.

AMT FÜR UMWELTSCHUTZ DES KANTONS SOLOTHURN 1995: *«Schadstoffbelastung des Bodens und der Vegetation im Bereich von Schiessanlagen».* Solothurn.

AMT FÜR UMWELTSCHUTZ DES KANTONS SOLOTHURN 1994: *«Untersuchungen der Schadstoffbelastung von Boden und Vegetation entlang von Kantonsstrassen sowie von Strassenwischgut».* Solothurn.

AMT FÜR UMWELTSCHUTZ DES KANTONS ST. GALLEN 1995: *«Schwermetallaufnahme durch Kulturpflanzen auf belasteten Böden – ein fünfjähriger, praxisnaher Freilandversuch an der Landwirtschaftlichen Schule Rheinhof».* 58 pp., Salez, St. Gallen.

AMT FÜR UMWELTSCHUTZ UND ENERGIE DES KANTONS BASEL-LANDSCHAFT, UMWELTSCHUTZLABOR 1994: *«Schwermetalle in Futterpflanzen von cadmiumbelasteten Landwirtschaftsböden».* 29 pp., Liestal.

AMT FÜR UMWELTSCHUTZ UND WASSERWIRTSCHAFT DES KANTONS THURGAU, BODENSCHUTZFACHSTELLE 1995: *«Schwermetallbelastung von Böden in Siedlungen, Ergebnisse einer Untersuchung in Arbon, Bischofszell, Frauenfeld, Kreuzlingen und Romanshorn».* 8 pp., Frauenfeld.

ANDREY D., RIBS T., WIRZ E. 1988: *«Monitoring-Programm – Schwermetalle in Lebensmitteln, II. Blei, Cadmium, Zink und Kupfer in Schweizer Kartoffeln».* Mitt.Gebiet.Lebensmittelunters.Hygiene, 79, 327–338.

BÄCHI B., FELDER D., GÜDEMANN O., LEIMGRUBER B., LOGEAY G., OETTERLI C., SPRUNGER D., WÜRMLI D., WYSSER M., CHRISTL I., VOEGELIN A. 2004: *«Gefährdungsabschätzung».* In: KRETZSCHMAR R. & SCHULIN R., Umgang mit Bodenbelastungen in Familiengärten der Stadt Zürich, project report of the Dep. für Umweltnaturwissenschaften, Institute for Terrestrial Ecology (ITE), ETH Zurich, WS 2003/04, p. 65–110.

BAG 1998: *«Vierter Schweizer Ernährungsbericht».* 649 pp., Berne.

BAG 1991: *«Dritter Schweizer Ernährungsbericht».* 564 pp., Berne.

BAG 1989: *«Schweizerisches Lebensmittelbuch».* Berne.

BALMER M., KULLI B. 1994: *«Der Einfluss von NTA auf die Zink- und Kupferaufnahme durch Lattich und Raygras».* Diploma report, 57 pp., Institute for Terrestrial Ecology (ITE), ETH Zurich.

BAUDEPARTEMENT DES KANTONS AARGAU, ABTEILUNG UMWELTSCHUTZ 1995: *«Bodenuntersuchungen in Gemüsegärten der Stadt Aarau».* 39 pp., Aarau.

BERG T., LICHT D. 2002: *«International legislation on trace elements as contaminants in food: a review».* Food Additives and Contaminants, 19, 916–927.

BERGMANN W. 1993: *«Ernährungsstörungen bei Kulturpflanzen».* 3rd ed., Gustav Fischer Verlag, Stuttgart.

BLUME H.-P. (ed.) 1992: *«Handbuch des Bodenschutzes – Bodenökologie und -belastung, vorbeugende und abwehrende Schutzmassnahmen».* 2nd ed., Ecomed, Landsberg/Lech.

BREITSCHWERDT A., HERRECHEN M., KLEIN M., KÖRDEL W., STORM A., WAHLE U. 2002: *«Erhebungsuntersuchungen zum Transfer organischer Schadstoffe vom Boden in Nahrungs- und Futterpflanzen und Ableitung von Prüfwerten nach dem Bundes-Bodenschutzgesetz».* Research report no. 299 73 298, 126 pp. (annexes), Umweltbundesamt, Dessau.

SAEFL 2005: *«Stickstoffhaltige Luftschadstoffe in der Schweiz».* Status report of the Eidg. Kommission für Lufthygiene, Environmental series no. 384, 170 pp., Berne.

SAEFL 2004a: *«Phosphor in Böden – Standortbestimmung Schweiz».* Environmental series no. 368, 174 pp., Berne.

SAEFL 2004b: *«Gewässerschutz – Verlagerung gelöster Stoffe durch den Boden ins Grundwasser».* Environmental series no. 349, 47 pp., Berne.

SAEFL 2004c: *«Schwermetallbelastete Böden – Quantitative Modelle zur Abschätzung der Gefährdung von Mensch und Umwelt».* Evaluation report (pdf), 68 pp., Berne (cf.: *www.umwelt-schweiz.ch/themen boden/publikationen boden).*

SAEFL 2003: *«Manual – Sampling and sample pretreatment for soil pollutant monitoring».* Environment in practice, 101 pp., Berne.

SAEFL 2001a: *«Commentary on the Ordinance of 1 July 1998 relating to impacts on the soil OIS)».* Environment in practice, 44 pp., Berne.

SAEFL 2001b: *«Guideline – Reuse of excavated soils».* Environment in practice, 20 pp., Berne.

SAEFL 1998: *«Richt-, Prüf- und Sanierungswerte für organische Schadstoffe im Boden – Fallbeispiel PAK».* Environmental materials no. 96, 111 pp., Berne.

SAEFL 1997a: *«Herleitung von Prüf- und Sanierungswerten für anorganische Schadstoffe im Boden».* Environmental materials no. 83, 100 pp., Berne.

SAEFL 1997b: *«Dioxine und Furane – Standortbestimmung, Beurteilungsgrundlagen, Massnahmen».* Environmental series no. 290, 127 pp., Berne.

SAEFL 1997c: *«Zur chemischen Belastung von Böden – eine synoptische Darstellung der Schadstoffgehalte und Bindungsstärken der Böden des NABO».* Environmental materials no. 77, 63 pp., Berne.

SAEFL 1996: *«Sols pollués – métaux lourds et plantes bioindicatrices».* Environmental materials no. 58, 245 pp., Berne.

CHAPMAN P.M., WANG F., JANSSEN C.R., GOULET R.R., KAMUNDE C.N. 2003: *«Conducting ecological risk assessments of inorganic metals and metalloids: current status».* Human and Ecological Risk Assessment, 9, 641–697.

D'MELLO J.P.F. (ed.) 2003: *«Food safety – contaminants and toxins».* CABI Publishing, 452 pp., Wallingford.

DELSCHEN T., KÖNIG W. 1998: *«Untersuchung und Beurteilung der Schadstoffbelastung von Kulturböden im Hinblick auf den Wirkungspfad Boden–Pflanze».* In: ROSENKRANZ *et al.* (ed.), Bodenschutz – updateble handbook, Kennzahl (code) 3550, E. Schmidt Verlag, Berlin.

DELSCHEN T., HEMBROCK-HEGER A., LEISNER-SAABER J., SOPCZAK D. 1999: *«Verhalten von PAK im System Boden/Pflanze».* Umweltwissenschaften und Schadstoffforschung, 11, 79–87.

DENZLER E. 1996: *«Bodensanierung mit Pflanzen, Zink- und Kupferaufnahme von indischem Senf und Lattich».* Diploma report, 75 pp., Institute for Terrestrial Ecology (ITE), ETH Zurich.
DESAULES A. 2004: *«Die Vergleichbarkeit von Schwermetallanalysen in Böden – Konsequenzen für die Klassifizierung und Abgrenzung von Belastungsflächen an einem Fallbeispiel bei Dornach (SO)».* Bulletin der Bodenkundlichen Gesellschaft der Schweiz, 27 pp.
DESAULES A., BÜHLER K., SCHERP K., SCHNELL S., ZURWEERA A. 1992: *«Bodenverschmutzung durch den Strassen- und Schienenverkehr in der Schweiz».* Eidgenössisches Verkehrs- und Energiewirtschaftsdepartement, Bundesamt für Strassenbau und Bundesamt für Umwelt, Wald und Landschaft (ed.), Environmental series no. 185, Berne.
DOMSCH K.H. 1998: *«Pestizide im Boden».* Wiley VCH, ISBN 3 527 28431 1, 585 pp., Weinheim/New York/Basel/Cambridge.
DVWK 1988: *«Filtereigenschaften des Bodens gegenüber Schadstoffen – Teil 1: Beurteilung der Fähigkeit von Böden, zugeführte Schwermetalle zu immobilisieren».* Merkblätter zur Wasserwirtschaft, 212, Deutscher Verband für Wasserwirtschaft und Kulturbau e.V., Bonn (ed.), Verlag Paul Parey, Hamburg and Berlin.
EIKMANN T., HEINRICH U., HEINZOW B., KONIETZKA R. (ed.) 1999: *«Gefährdungsabschätzung von Umweltschadstoffen – updatable handbook toxikologischer Basisdaten und ihre Bewertung».* ISBN 3 503 050830 3, Erich Schmidt Verlag, Berlin.
EIKMANN T., KLOKE A. 1993: *«Nutzungs- und schutzgutbezogene Orientierungswerte für (Schad-)Stoffe in Böden».* In: ROSENKRANZ D., BACHMANN G., KÖNIG W., EINSELE G. (ed.): *«Bodenschutz – Ergänzbares Handbuch der Massnahmen und Empfehlungen für Schutz, Pflege und Sanierung von Böden, Landschaft und Grundwasser»*, Kennzahl (code) 3590, Erich Schmidt Verlag, Berlin.
EURACHEM/CITAC Guide 2000: *«Quantifying Uncertainty in Analytical Measurement».* Laboratory of the Government Chemist, 2nd ed, 120 pp., London.
EURACHEM 1995: *«Quantifying Uncertainty in Analytical Measurement».* ISBN 0 948926 08 2, 87 pp., London.
EUROPEAN CHEMICALS BUREAU 2003: *«Technical Guidance Document on Risk Assessment».* TGD Part II, Institute for Health and Consumer Protection, EUR 20418 EN/2, 328 p., Luxembourg.
FIEDLER H. 2003: *«Dioxins and Furans (PCDD/PCDF ».* Handbook of Environmental Chemistry, vol. 3O, 123–201.
FIEDLER H.J., RÖSLER, H.J. (ed.) 1988: *«Spurenelemente in der Umwelt».* Enke Verlag, Stuttgart.
FRISCHE T., MEBES K.-H., FILSER J. 2003: *«Assessing the bioavailability of contaminants in soils: a review on recent concepts».* Research report no. 201 64 214, 102 pp., Agency for the Environment, Dessau.
FROSSARD R., BONO R., SCHMUTZ D., BUSER A., SIMON P., WENK P., SCHAUB S. 2000: *«Cadmium in acht Weizensorten – Ergebnisse eines Anbauversuchs in Nenzlingen, Basel-Landschaft».* Mitt.Geb.Lebensm.Hyg., 91, 473–483.
GEORGOPOULOS P.G., ROY A., YONONE-LIOY M. J., OPIEKUN R. E., LIOY P. J. 2001: *«Environmental copper – its dynamics and human exposure issues».* J.Toxicol.Environ.Health, Part B 4, 341–394.

GERECHT B. 2002: *«Familiengärten – Altlast oder Ressource?».* Diploma report, 65 pp., Institute for Terrestrial Ecology (ITE), ETH Zurich.

GIRARD M.-C., WALTER C., REMY J.-C., BERTHELIN J., MOREL J.-L. 2005: *«Sols et environnement».* ISBN 2 10005 520 8, 832 p., Collection Sciences Sup., Paris.

GISI U., SCHENKER R., SCHULIN R., STADELMANN F.X., STICHER H. 1997: *«Bodenökologie».* 350 pp., Thieme Verlag (2nd ed.), Stuttgart.

GLÜKLER M., MÄDER K., STEIDLE F. 1995: *«Nachuntersuchungen zur Schwermetallbelastung der Böden auf dem Familiengartenareal Zurich-Juchhof, Abklärungen zur Herkunft der Belastung, Beurteilung der gesundheitlichen Risiken und Erarbeitung eines Erkundungskonzeptes».* Diploma report, 124 pp., Institute for Terrestrial Ecology (ITE), ETH Zurich.

GOBAT J.-M., ARAGNO M., MATTHEY W. 1998: *«Le Sol vivant».* Collection gérer l'environnement no. 14, Presses polytechniques et universitaires romandes, ISBN 2 88074 367 2, 519 pp., Lausanne.

GREIM H (Hrsg.) 1972/2004: *«Gesundheitsschädliche Arbeitsstoffe – Toxikologisch-arbeitsmedizinische Begründung von MAK-Werten».* Updatable handbook, Deutsche Forschungsgemeinschaft, ISSN 0930–1984, Wiley-VCH Verlag GmbH & Co. KgaA, Weinheim, Germany.

GRÜNENFELDER B., SCHMIDLI F. 1998: *«Schwermetallbilanzierung belasteter Böden und ihre Anwendung im Rahmen der sanften Bodensanierung».* Diploma report, 81 pp., Institute for Terrestrial Ecology (ITE), ETH Zurich.

GSPONER R. 1996: *«Ursachendifferenziertes Vorgehen zur verdachtsorientierten Erkundung von Schwermetallbelastungen im Boden».* Dissertation ETH Zurich, no. 11 862.

GUPTA S.K. 1991: *«Assessment of ecotoxicological risk of accumulated metals in soils with the help of chemical methods standardized through biological tests».* In: VERNET J.-P. (ed.), Heavy metals in the environment, p. 55–65, Elsevier, Amsterdam.

GUYONNET D., BOURGINE B., DUBOIS D., FARGIER H., CÔME B., CHILÈS J.-P. 2003: *«Hybrid approach for addressing uncertainty in risk assessments».* J.Environ.Engineering, 129, 68–78.

HAMMER D. 1997: *«Schwermetallakkumulation durch Weidenstecklinge auf vier Schweizer Böden – Aufnahme-Effizienz in Abhängigkeit des Bodens».* Diploma report, 47 pp., Institute for Terrestrial Ecology (ITE), ETH Zurich.

HAPKE H.-J. 1988: *«Toxikologie für Veterinärmediziner».* 259 pp., Enke Verlag, Stuttgart.

HASSAUER M., KALBERLAH F., GRIEM P. 2001: *«Zink und Verbindungen».* In: EIKMANN T., HEINRICH U., HEINZOW B., KONIETZKA R. (eds.), Gefährdungsabschätzung von Umweltschadstoffen, updatable handbook, Toxikologische Basisdaten und ihrer Bewertung, Kennzahl (code) D 985, Erich Schmidt Verlag, Berlin.

HEPPERLE E.U. 2001: *«Umsetzung des Verursacherprinzips bei bodenschutzrechtlichen Massnahmen».* Umweltrecht in der Praxis, 15, no. 10, 1017–1038.

HORNBURG V., BRÜMMER, G.W. 1993: *«Verhalten von Schwermetallen in Böden – Untersuchungen zur Schwermetallmobilität».* Z.Pflanzenernähr.Bodenk., 156, 467–477.

HORWITZ W. 2003: *«The certainty of uncertainty».* J.Associat.Offic.Anal.Chemists (AOAC) International, 86, no. 1, 109–111.

IPE 1994: *«Chemical composition of various plant species».* International Plant-Analytical Exchange, Wageningen Agricultural University, Netherlands.
JARDINE C.G., HRUDEY S.E., SHORTREED J.H., CRAIG L., KREWSKI D., FURGAL C., MCCOLL S. 2003: *«Risk management frameworks for human health and environmental risks».* J.Toxicol.Environ.Health, Part B 6, 569–641.
KELLER T., DESAULES A. 2001: *«Kartiergrundlagen zur Bestimmung der Bodenempfindlichkeit gegenüber anorganischen Schadstoffeinträgen in der Schweiz».* Agroscope FAL Reckenholz, Zurich.
KANTONALES LABORATORIUM AARGAU 1995: *«Schwermetalle im Gemüse aus Aarauer Gärten».* 13 pp., Aarau.
KESSLER J. 1993: *«Schwermetalle in der Tierproduktion».* Landwirtschaft Schweiz, 6, 273–277.
KIRCHGESSNER M. 1997: *«Tierernährung».* 11. Auflage, DLG, Frankfurt a.M.
LANDESANSTALT FÜR UMWELTSCHUTZ BADEN-WÜRTTEMBERG (ed.) 1997a: *«Stoffbericht – Polychlorierte Biphenyle (PCB)».* Texte und Berichte zur Altlastenbearbeitung, 121 pp., 16/95.
LANDESANSTALT FÜR UMWELTSCHUTZ BADEN-WÜRTTEMBERG (ed.) 1997b: *«Stoffbericht Polyzyklische aromatische Kohlenwasserstoffe (PAK)».* Texte und Berichte zur Altlastenbearbeitung, 249 pp., 34/97.
LITZ N., WILCKE W., WILKE B.M. 2005: *«Bodengefährdende Stoffe – Bewertung, Stoffdaten, Ökotoxikologie, Sanierung».* Updatable handbook, ecomed, ISBN 3 609 52001 9, Hüthig Jehlen Rahm GmbH, Landsberg am Lech.
LUDWIG C., MÄRKI M. 1997: *«Schwermetallaufnahme von Futterrüben in Abhängigkeit von der Düngung – Risikoabschätzung für Pflanze, Mensch und Tier».* Diploma report, 45 pp., Institute for Terrestrial Ecology (ITE), ETH Zurich.
MERGENTHALER B., RICHNER T. 2002: *«Mobilität und geochemisches Verhalten von Antimon im Boden von Schiessanlagen».* Diploma report, 54 pp., Institute for Terrestrial Ecology (ITE), ETH Zurich.
MERIAN E. 1991: *«Metals and their compounds in the environment – occurrence, analysis, and biological relevance».* VCH Verlagsgesellschaft, ISBN 3 527 26521 X, 1438 pp., Weinheim/New York/Basel/Cambridge.
MEULI R.G. 1997: *«Geostatistical Analysis of Regional Soil Contamination by Heavy Metals».* Diss. ETHZ no. 12 121, 191 pp., Zürich
MOSCHANDREAS D.J., KARUCHIT S. 2002: *«Scenario-model-parameter: a new method of cumulative risk uncertainty analysis».* Environment International, 28, 247–261.
MUNTWYLER T., SCHAUB D., KUHN E., ARNET R. 2002: *«Landwirtschaftliche Nutzung im Bereich von Schiessanlagen – Gefährdungsabschätzung».* Umwelt Aargau, Sondernummer 14, 34 pp., Aarau.
NISBET I.C.T, LAGOY P.K. 1992: *«Toxic Equivalent Factors for Polycyclic Aromatic Hydrocarbons (PAHs)».* Reg.Toxicol.Pharm., 16, 290–300.
NRC 1980: *«Mineral Tolerance for Domestic Animals».* National Research Council, 577 pp., Washington D.C.
REILLY C. 2002: *«Metal contamination of food – Its significance for food quality and human health».* 266 pp., Blackwell, 3rd edition, Oxford.
RIGON S., SCHIB E., STENZ B. 1993: *«Die ehemalige Deponie Les Abattes bei Le Locle – Untersuchungen zu den Auswirkungen der schwermetallbelasteten Auflageschicht auf Pflanzen und Untergrund».* Diploma report, 209 pp., Institute for Terrestrial Ecology (ITE), ETH Zurich.

ROSENKRANZ D., BACHMANN G., KÖNIG W., EINSELE G. (eds.) 1988: *«Bodenschutz – Ergänzbares Handbuch der Massnahmen und Empfehlungen für Schutz, Pflege und Sanierung von Böden, Landschaften und Grundwasser».* ISBN 3 503 02718 1, Erich Schmidt Verlag, Berlin.

SCHEFFER F., SCHACHTSCHABEL P. 2002: *«Lehrbuch Bodenkunde».* 15th ed., Spektrum, Heidelberg.

SCHNEIDER K., KALBERLAH F. 2000: *«Kupfer und Verbindungen».* In: EIKMANN T., HEINRICH U., HEINZOW B., KONIETZKA R. (ed.), Gefährdungsabschätzung von Umweltschadstoffen, updatable handbook, Toxikologische Basisdaten und ihre Bewertung, Kennzahl (code) D 577, Erich Schmidt Verlag, Berlin.

SCHULIN R., DESAULES A., WEBSTER R., VON STEIGER B. 1993: *«Soil monitoring – early detection and surveying of soil contamination and degradation».* Monte Verità Proceedings, Birkhäuser Verlag, 362 pp., Basel.

STARR C., WHIPPLE C. 1980: *«Risks of risk decision».* Science, no.208, 1114–1119.

TSCHANNEN P. 1999: *«Erläuterungen zum Bodenschutz (Art. 33–35)».* In: Kommentar zum Umweltschutzgesetz (comments on the Law relating to the protection of the environment), Vereinigung für Umweltrecht und Helen Keller (ed.), Zurich.

WALTHERT L. et al 2004, and BLASER P. *et al.* 2005: *«Waldböden der Schweiz».*Vol. 1 and 2, ISBN 3 03905 131 8, 768 pp., resp. 920 pp., h.e.p. verlag ag, Berne.

WATSON D.H. (ed.) 2001: *«Food chemical safety».* Vol. 1, Contaminants, 322 pp., CRC Press, Boca Raton.

WENK P., BONO R., DUBOIS J.P., GENOLET F. 1997: *«Cadmium in Böden und Getreide im Gebiet Blauen/Nenzlingen, Basel-Landschaft».* Mitt.Geb.Lebensm.Hyg., 88, 570–592.

WHO 2002: *«Safety evaluation of certain food additives and contaminants».* World Health Organization, food additive series no. 48, 692 pp., Geneva.

WILLIAMS P.R.D., PAUSTENBACH D.J. 2002: *«Risk characterization, Principles and practice».* J.Toxicol.Environ.Health, Part B 5, 337–406.

## Additional information on risk assessment

EU legislation, European Union (European legislation) available in internet under: http://europa.eu.int/documents/eur-lex/index_de.htm

UBA 1998: *«Analytical model – Exposition der Schutzgüter Umwelt und Mensch mit Schadstoffen (UMS)».* Version 2.10, ARGE Fresenius, focon u. Chemlog GBR, IfUA GmbH, Berlin.

WHO/FAO 2003: *«Summary and conclusions of the Joint FAO/WHO Expert committee on food additives (JECFA)»* – 61st meeting in Rome, 10–19 June 2003; Annex 4 on Cd.