BUWAL Bundesamt für Umwelt, Wald und Landschaft
OFEFP Office fédéral de l'environnement, des forêts et du paysage
UFAFP Ufficio federale dell'ambiente, delle foreste e del paesaggio
SAEFL Swiss Agency for the Environment, Forests and Landscape
Swiss Federal Research Station for Agroecology and Agriculture FAL
EPF Lausanne ENAC ISTE CECOTOX

FAL

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Literature based Ecotoxicological Risk Assessment

Literaturbasierte ökotoxikologische Risikoabschätzung

Final report of Module 5a
of the Project Organic pollutants in compost and digestate in Switzerland

Report in English with abstract in German

Schlussbericht von Modul 5a
des Projekts Organische Schadstoffe in Kompost und Gärgut der Schweiz

Bericht auf Englisch mit Zusammenfassung auf Deutsch

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List of Abbreviations

LC50:	Lethal Concentration causing 50% mortality in the test species.
LD50:	Lethal Dose causing 50% mortality in the test species.
LR50:	Lethal Rate causing 50% mortality in the test species.
EC50:	Concentration causing an Effect in 50% of the test species. An effect can be immobilisation, reduced feeding, behavioural changes, etc.
NOEC:	No Observed Effect Concentration. Highest concentration in a study with a range of concentrations where no effects were observed.
NOEL:	No Observed Effect Level. Highest dose in a study with several dosages where no effects were observed.
DT50:	Time it takes in a dissipation study until 50% of the initial amount or concentration of a chemical substance has disappeared.
TER:	Toxicity Exposure Ratio; subscripts denote time-scales (a = acute, st = short-term, lt = long-term)
HQ:	Hazard Quotient
PEC:	Predicted Environmental Concentration
E value:	Beneficial capacity: an indicator of combined effects of treatment on survival and reproduction of arthropods.
FIV data:	Maximum residue levels in crops according to the Swiss Ordinance on Foreign Substances and Components (Verordnung über Fremd- und Inhaltsstoffe in Lebensmitteln, FIV)
GLP:	Good Laboratory Practise
GAP:	Good Agricultural Practise
dw:	Dry weight
PAHs:	Polycyclic aromatic hydrocarbons
PBDEs:	Polybrominated diphenylethers
PCBs:	Polychlorinated biphenyls
PCDD:	Polychlorinated dibenzodioxin
ww:	Wet weight

Abstract

Compost and digestate (in the following the term compost includes digestates) can be recycled in agriculture as fertilizer, soil improver and growth substrates. Besides their beneficial components these biogenic waste products may also contain anthropogenic ubiquitous chemical substances and pesticides. Little data about these organic substances in Swiss compost is available and it is therefore difficult to evaluate potential risks associated with the recycling of compost. In order to reveal these gaps and to contribute to a safe and sustainable recycling a risk assessment of seventeen chemical substances was carried out based on literature research.

For three substances (PCDD, polychlorinated Dibenzodioxins; PAH, polycyclic aromatic hydrocarbons; PCB, polychlorinated biphenyls) sufficient data was available to exclude an unacceptable risk. Only for atrazine an unacceptable risk for soil organisms living directly in the compost was found based on the current knowledge. The application of compost containing atrazine or captan to soils does not show an elevated risk. For the remaining twelve substances (bisphenol A, chlorpyrifos, cyprodinil, folpet, iprodione, metolachlor, phthalates, PBDEs (polybrominated diphenylethers), procymidone, thiabendazole, trifluralin, vinclozolin) insufficient data about their concentrations in Swiss compost or their ecotoxicological effects exist to reliably assess the risks. In order to conclusively assess the ecotoxicological relevance of these chemical substances in Swiss compost further ecotoxicological, environmental and chemical information are needed. Considering the possible beneficial effects of compost and the potential for a wide usage these gaps in knowledge cannot be ignored. It is suggested that for a refined risk assessment experts and stakeholders should be involved in deciding which gaps have to be filled and in judging the risks in the light of possible benefits.

Zusammenfassung

Kompost und Gärgut (im folgenden bezieht sich der Ausdruck Kompost auch auf Gärgut) können in der Landwirtschaft als Dünger, Bodenverbesserer und Pflanzensubstrat wiederverwendet werden. Neben ihren nützlichen Bestandteilen können diese biogenen Abfälle auch anthropogene ubiquitäre chemische Substanzen und Pestizide enthalten. Es ist nur wenig über diese organischen Substanzen im Schweizer Kompost bekannt und es ist daher schwierig die Risiken, die mit der Wiederverwertung von Kompost einhergehen zu beurteilen. Um diese Kenntnislücken aufzuzeigen und zu einer sicheren und nachhaltigen Wiederverwertung beizutragen, wurde eine Risikoanalyse von siebzehn chemischen Substanzen basierend auf einer Literaturstudie durchgeführt.

Für drei Substanzen (PCDD, polychlorierte Dibenzodioxine; PAK, polyzyklische aromatische Kohlenwasserstoffe; PCB, polychlorierte Biphenyle) waren genügend Daten vorhanden, um ein unannehmbares Risiko auszuschliessen. Lediglich für Atrazin zeigte sich auf Grund der vorliegenden Daten ein unannehmbares Risiko für Bodenorganismen, die direkt im Kompost leben. Bei der Einarbeitung von Kompost mit Atrazin oder Captan in den Boden ist kein erhöhtes Risiko zu erwarten. Für die weitern zwölf Substanzen (Bisphenol A, Chlorpyrifos, Cyprodinil, Folpet, Iprodion, Metolachlor, Phthalate, PBDE (polybromierte Diphenylether), Procymidon, Thiabendazol, Trifluralin, Vinclozolin) waren die Daten bezüglich ihrer Konzentration im Schweizer Kompost oder ihrer ökotoxikologischen Wirkung nicht ausreichend, um das Risiko zuverlässig abzuschätzen. Um die ökotoxikologische Bedeutung dieser chemischen Substanzen im Schweizer Kompost abschliessend beurteilen zu können, werden weitere ökotoxikologische und umweltchemische Informationen benötigt. In Anbetracht der positiven Wirkung von Kompost und dem Potential für eine verbreitete Verwendung können diese Wissenslücken nicht ignoriert werden. Es wird vorgeschlagen, für eine verfeinerte Risikoabschätzung Fachleute und Interessierte beizuziehen, um zu entscheiden welche Lücken gefüllt werden müssen, und wie mögliche Risiken im Lichte der positiven Wirkung von Kompost zu gewichten sind.

1. Introduction

A part of the biogenic waste from households, industry or agriculture can be converted into compost or digestates (in the following the term compost includes digestates). Composting reduces volume and water content of the biogenic waste, destroys potential pathogens, and odour-producing nitrogenous and sulphurous compounds. Composted biogenic waste can be recycled in agriculture, landscaping or gardening as plant fertilizer, soil improver or as growth substrate. As about 600’000 t of biogenic waste are recycled by composting each year in Switzerland, this practise has a significant ecologic and economic importance.

In order to promote compost recycling as part of a sustainable agriculture, it is important to understand not only the beneficial effects of compost on the soil quality, but also the potential harmful impact its usage could have on the environment. To guarantee a safe application of compost in Swiss agriculture, a wide-ranging project entitled “Organic pollutants in compost and digestates in Switzerland” was launched. It is a joint project of FAL (Eidgenössische Forschungsanstalt für Agrarökologie und Landbau) and EPFL (Laboratoire de chimie environmentale et écotoxicologie) financed by BUWAL. The subproject (Module 5a) “Literature based ecotoxicological risk assessment” aims at assessing the risk of organic substances in compost, originating from atmospheric deposition or pesticides, on organisms of the soil community.

The soil community in a square meter can contain 10^3 earthworms, snails, isopods or beetles, 10^5 collembola or enchytraeids, 10^6 soil mites, 10^8 nematodes and up to10^{34} microorganisms (bacteria, algae, fungi, protozoa). The main function of soil organisms is the degradation and conversion of organic substances into inorganic compounds, which can be taken up by plants. Soil organisms thus contribute to the synthesis of new compounds, mobilisation of nutrients, mixing of soil and creation of a soil structure, which ultimately regulates the water and air balance of the soil. Furthermore, soil organisms are often members of complex food chains. Key organisms, either with regards to soil quality or as biological pest control, are earthworms, collembola (springtails), soil mites, beetles, other invertebrates and soil microorganisms. These organisms are also responsible for transforming plant material into compost.

An ecotoxicological risk assessment relates the environmental concentration of a compound to its ecotoxicological effects in order to quantify the impact of a compound on the ecosystem. It can only be carried out if the ecotoxic effects of a compound on potentially affected species as well as the concentration of the compound are known. In order to assess the risk the following questions must be answered:

- Are the organic chemical substances in compost ecotoxic?
- In which concentrations do they occur in compost in Switzerland?
- Is the risk to organisms due to the compost recycling acceptable?

This way reliable and meaningful recommendations to the quality and usage of composts can be made.

In this project the emphasis was placed on the ecotoxicological risk of the ubiquitous chemical substances bisphenol A, PCDD (polychlorinated dibenzodioxins), PAH (polycyclic aromatic hydrocarbons), PCB (polychlorinated biphenyls), phthalates (DEHP, DBP, DEP) and PBDEs (polybrominated diphenylethers), as well as on the pesticides atrazine, captan, chlorpyrifos, cyprodinil, folpet, iprodione, metolachlor, procymidone, thiabendazole, trifluralin and vinclozolin. The outcome of this study forms the basis for more focused investigations, which will ultimately answer the question whether and under which circumstances the safe use of compost recycling in agriculture will be possible. In particular it will contribute to the decision whether ecotoxicological studies have to be carried out within the module 5b of the study “Organic pollutants in compost and digestates in Switzerland”.

2. Methods

2.1 Ecotoxicity

The assessment of the ecotoxicity of the chemical substances was based on literature research (Annex I). Combinations of about forty keywords were used to search for suitable literature from the last thirty years, including laboratory ecotoxicity tests either according to guidelines or not, and field studies. Scientific publications, reference literature (i.e. The Pesticide Manual) and FAL-internal as well as Internet databases were used. The quality of the studies was assessed and only trustworthy studies were included in the risk assessment. If there were contradictions as to terminology, units or calculations in the text, the study was not considered trustworthy. If a study was conducted in a controlled and comprehensive manner, but not according to guidelines, it was still considered trustworthy.

The following species or taxonomic groups were considered in the literature search:

- Oligochaete worms have a great impact on the soil quality as they help aerate the soil and increase its fertility by manuring it with leaf litter. Due to their long life span chronic studies are especially relevant. The standard earthworm species for ecotoxicological studies is *Eisenia fetida*. Enchytraeids, also known as potworms, are smaller than earthworms and are sometimes used as test species. *Tubifex tubifex* was not considered a representative species for the agricultural environment, as it lives in muddy sand.
- Collembola are abundant, typically soil surface dwelling species, which feed on fungi, bacteria and decaying leaf matter. Collembola are key soil decomposers and form an important link in soil food chains. They have a lifespan of 2-5 months up to a year.
- Some soil mites are predacious and feed on collembola or plant-feeding spider mites; others feed on microorganisms and plant remains.
- Ground beetles and lady beetles feed on insect pests (i.e. aphids, caterpillars) and are therefore worthwhile protection in an agricultural system. Immature stages of ground beetles are distinctly different from adults and are often found within the top few centimetres of soil. *Orius insidiosus* lives on the foliage of crops and feeds on thripes, mites, aphids and small caterpillars.
- Other invertebrates include isopods, nematodes, spiders and beneficial mites. Isopods fulfil roles of micrograzers and detritivores. The terrestrial isopods Oniscoidea (*Porcellio scaber*, *Oniscus asellus*) live in damp conditions. Nematodes belong to the microfauna and are sometimes referred to as roundworms. They feed on bacteria, fungi and plant roots. Spiders can be important in controlling insect pests such as beetles, caterpillars, leafhoppers and aphids. The beneficial predatory mite *Typhlodromus pyri* is not a soil organism, but is often used as a substitute species for arthropods in risk assessment studies.
- Microorganisms (bacteria, fungi, algae) are the principal agents of decay, reducing plant and animal residues to their component minerals. The vast cyclic movements of chemical elements such as carbon and nitrogen through the soil and air could not proceed without these microorganisms.

2.2 Exposure

Composts and digestates are produced from biogenic wastes from gardens, public green areas, households and industry. Due to their origin these biogenic wastes can contain pesticides or ubiquitous pollutants. As composts and digestates are recycled in agriculture and gardens, natural occurring organisms in agricultural fields or horticultural beds can be exposed to the chemical substances of these wastes.

The concentrations of the chemical substances in compost, which are to be used for the risk assessment (see Annex 1 of the project description “Organic pollutants in compost and digestates in Switzerland”), should represent realistic worst-case concentrations. For ubiquitous organic substances realistic worst-case concentrations were selected by expert judgment from literature data. For pesticides the worst-case concentrations were taken as the maximum residue level in a relevant crop according to the Swiss Ordinance on Foreign Substances and Components (Verordnung über Fremd- und Inhaltsstoffe in Lebensmitteln, FIV). The compliance to these maximum residue levels is routinely checked by cantonal laboratories and they therefore represent worst-case concentrations. Degradation and dilution by other organic residues are not taken into account in these estimated concentrations. As the maximum residue levels are expressed per wet weight of crop, a water content of 90% in the crops was assumed to convert the concentrations to dry weight. Where available the measured concentrations of pesticides in compost were also taken from literature.

Composting can degrade various organic compounds, especially if the process is carried out with proper aeration, water, C:N ratios and duration. Rapid degradation of xenobiotics commonly occurs during the first thirty days. Organophosphates and carbamate insecticides and most herbicides decompose during composting. Organic compounds can be altered during composting by mineralization, partial degradation, adsorption to compost and volatilisation. Degradation does not always render a compound less toxic and the secondary compounds may be as, or more toxic than the original pesticides. However, organochlorine compounds are resistant to biodegradation. From the investigated chemical substances, atrazine, chlorpyrifos, PCDD, iprodione, PAH, PCB, phthalates, PBDEs, thiabendazole, trifluralin and vinclozolin are potentially persistent in soil.

The predicted environmental concentrations (PEC) were calculated for different usage scenarios (Table 1). Scenario I assumed that compost was used undiluted as a growth medium in greenhouses. Scenario II and III considered that compost might be used for soil improvements with 100 t dw/ha every 10 years (Anonymous, 1986). Scenario IV and V take into account the use of compost as fertilizer and assumes that 10 t/ha are used each year. In order to calculate the concentration in the soil column in mg/kg soil (PEC_{soil}), two depths were chosen to which the compost can be incorporated: 5 cm was chosen based on an EC proposal for the risk assessment of pesticides and 20 cm as it represents a more realistic depth, especially for the usage of compost as soil improver. The average density of agricultural soil was taken to be 1.5 g/cm^3. The quantity of a chemical substance per soil surface area in kg/ha (PEC_{area}) was calculated for the application of 100 t compost/ha and 10 t compost/ha.

Table 1: Scenarios of compost usage, differing in the amount of compost applied once (t/ha) and incubation depth (cm). Scenarios I-V were used for the calculation of PECsoil and scenario II and IV (without consideration of the depth) for PECarea.

Scenario I	Scenario II	Scenario III	Scenario IV	Scenario V
Directly in compost	100 t/ha in 5 cm	100 t/ha in 20 cm	10 t/ha in 5 cm	10 t/ha in 20 cm

2.3 Risk Assessment

In order to assess the risk, indicators were calculated, which reflect the relation between toxicity endpoints (Lethal Concentration causing 50% mortality (LC50), No Observed Effect Concentration (NOEC), etc.) and the predicted exposure. These indicators are called TER (Toxicity Exposure Ratio) or HQ (Hazard Quotient). If several species were investigated for one group of organisms, the most sensitive species was used. The consideration being that if the most sensitive species is protected all other species from the same organism group should not be at risk either. Where large discrepancies in the measured concentrations for one compound existed, two or more concentrations were used for the risk assessment. To calculate the indicators (TER) for worms and collembola, exposure and effect concentrations were often expressed in mg/kg soil or feed; for mites, beetles and other invertebrates exposure and effect concentrations were often expressed in kg/ha to calculate the HQ. One differentiates between a short-term (TER_{st}) and a long-term (TER_{lt}) TER, whereby the acute studies (LC50) allow the estimation of the short-term risks and the NOEC, determined through chronic studies, allows the long-term assessment.

The TER was calculated by dividing the toxicity endpoint (LC50, NOEC) by the predicted environmental concentration (PEC), according to the uniform principles of the EU used to assess the risk of pesticides (Anonymous, 1991). If the effect was expressed in kg/ha, then the HQ was calculated by dividing the application rate through the effect concentration according to the ESCORT II document (Candolfi et al., 2001).

In general, a number of uncertainties are linked to a risk assessment. First of all, the toxicological endpoints are connected with an uncertainty due to the validity of the studies. A further uncertainty is caused by the natural spatial and temporal variability of the species composition and behaviour. Additionally, an uncertainty exists with regards to the predicted exposure. And finally, lack of ecotoxicological data may contribute to uncertainties.

In order to account for uncertainties, trigger values were introduced according to 91/414/EEC to assess the acceptability of risks. The trigger values consider the uncertainties due to the extrapolation from acute effects to chronic risks, from laboratory data to field situations and from one substitute test species to multiple species. Although founded on general experience in risk assessment, the critical TERs are somewhat arbitrary and the exact contribution of each factor to the uncertainties has not been specified yet. The critical HQ for arthropods was established according to a validation procedure where the HQ was compared with (semi)field data. The predictive power of this critical HQ seems therefore better defined. However, the validation of the critical HQ was based on spray applications and data from glass plate tests only. If a TER or HQ is beyond one of the trigger values, it could mean that

a) a chemical substance poses an unacceptable risk to soil organisms or
b) there is not enough information available to exclude a risk to soil organisms, which means that further studies and expert judgment (refined risk assessment) are necessary.

The trigger values suggested in 91/414/EEC for soil organisms are as follows: If the risk assessment gives a TER_{st} >10 or a TER_{lt} >5, the risk is usually considered acceptable. The long-term TER is only used in conjunction with the short-term TER, i.e., if TER_{st} <10 or if the compound is persistent according to 91/414/EEC Annex II. If the resulting HQ is below the critical value of 2 the risk is usually considered acceptable.

These trigger values were established for the assessment of pesticides, which is based on an ecotoxicological data set for a range of test species from the whole ecosystem according to EU guidelines. Therefore, in order to apply these trigger values an ample dossier has to be available. As the studies used in this risk assessment were rarely established according to guidelines and focused only on the soil ecosystem, a procedure was established to account for uncertainties due to the quality and quantity of studies. For this, two additional assessment levels with increased trigger values (Table 2) were included.

Assessment level I, the standard EU-approach, was used if several GLP (according to Good Laboratory Practise) or trustworthy studies existed. Assessment level II was applied if the studies were considered to be not trustworthy or just one species was investigated. Assessment level III was necessary if only one rudimentary study was available.

The indicators were calculated for the measured and estimated concentrations and are presented in Annex II. The colour coding in Annex II facilitates the judgement up to which assessment level the risk is acceptable. In order to illustrate the risk, the ratios between the indicators (TER, HQ) and the trigger values at the appropriate assessment levels were calculated and presented in table format in the risk assessment (p. 22 ff.). As not for every pesticide measured concentrations were available the ratios were only calculated for the FIV-based data. Factors <1 indicate an unacceptable risk.

Table 2: Assessment levels and trigger values used for the risk assessment of each taxonomic group based on the quality and quantity of available ecotoxicological studies.

Assessment level	Criteria	TER_{st}	TER_{lt}	HQ
I	GLP or trustworthy studies with several species	10	5	2
II	Not trustworthy studies or just one species	100	50	0.2
III	Not trustworthy studies and only one species	1000	500	0.02

The risk assessment performed by this procedure is not comprehensive as a number of considerations had to be excluded:

- Antagonistic or synergistic toxic effects due to the combination of several chemical substances in the compost.
- Toxicity of metabolites.
- Comparison to risks of natural degradation products from plant material or secondary plant compounds.
- Bioavailability of the chemical substances due to soil characteristics (adsorbed, complexed, dissolved) and thus changes in their toxicity.
- Exposure of aquatic species due to runoff or leaching from fields treated with biogenic wastes.
- Bioaccumulation of the chemical compounds in soil organisms.
- Secondary toxicity for birds or mammals due to feeding on contaminated soil dwelling organisms.
- Accumulation of chemical compounds in the soil due to multiple applications of compost.
- Potential that the application of compost decreases the toxicity of pollutants originally present in soil by increased degradation due to the addition of organic material.
- Degradation of chemical compounds in the compost after its application on soil.

3. Results and Discussion

3.1 Ecotoxicity

A detailed review of the ecotoxicological studies of the chemical substances with references is included in Annex I. In the following the studies are summarized for each chemical substance and class of organisms.

Data for birds and mammals are reported in Annex I for atrazine, captan, chlorpyrifos, folpet, iprodione, metolachlor, PCB, and thiabendazole.

The literature research for the ecotoxicological data of the seventeen chemical substances revealed great gaps in the documentation of the terrestrial ecotoxicity. For bisphenol A, polybrominated diphenylethers, and procymidon no data on terrestrial ecotoxicology could be found. Only for atrazine, captan, chlorpyrifos and PAH numerous studies were available.

The endpoints printed in bold were used for the risk assessment.

3.1.1 Atrazine

In acute toxicity studies *Eisenia fetida* was more sensitive than *Lumbricus terrestris*. The most sensitive LC50 of **78 mg/kg** soil for *Eisenia fetida* was taken from the pesticide manual. For chronic exposure a NOEC of **32 mg/kg** was taken from a rudimentary summary on *Eudrilus eugeniae*.

In a simple study with sterile sand substrate the collembola *Onychiurus armatus* and *O. apuanicus* proved the most sensitive species in comparison to another four species cited in the literature. The LC50 were 20 mg/kg and **17.2 mg/kg** respectively, and the NOEC **<2.5 mg/kg**. However, the usage of terminology was confusing in this study. In a feeding study with *Orchesella cincta* acute and chronic (reproductive) toxic effects were observed in culture pots. The study was not carried out according to guidelines, but seems controlled and reliable. The LC50 after 42 d was 224 mg/kg feed and the NOEC 40 mg/kg feed. At concentrations above the NOEC oviposition was affected and long-term effects can therefore be expected. In a field study in Egypt the abundance of *Entomobrya musatica* was significantly affected at 4 kg/ha, which is equivalent to 5.3 mg/kg soil (according to the criteria of scenario II). The sensitivity of this species in the field study was thus comparable to *Onychiurus* in the laboratory. For this reason the endpoint for *Onychiurus* was used for the risk assessment.

No toxic effects of atrazine on beetles (*Amara* sp*.*, *Agonum* sp., *Pterostichus* sp*.*, *Anisodactylus* sp., *Harpalus* sp.*)* were observed in the laboratory or in the field at an application rate of **2.24 kg/ha**.

Atrazine seems to be non-toxic to *Chironomous tentans* at high concentrations (10 mg/l), whereas concentrations of 0.04-0.2 mg/l increased the toxicity of chlorpyrifos. In the field, no losses in the abundance of microarthropods by the application of **2 kg/ha** were observed. Observed losses at 6 kg/ha recovered within one month, whereas in another study a decrease in abundance of soil protozoa, mite fauna, collembola (*Hypogastruridae* and *Symphyleona*), insect larvae and to a small extent of *enchytraeidae* was observed for four months at 5 and 8 kg/ha.

At concentrations >100 mg/kg soil nitrification was significantly decreased for at least 90 d, whereas 10 mg/kg did not affect populations of actinomycetes, bacteria and fungi over 2 months.

Synopsis: Ecotoxicological data were found for worms, collembola, five carabid species, other invertebrates and microorganisms. Atrazine was not toxic to beetles in the field or laboratory at the tested concentration. The most sensitive species seem to be collembola. The recovery time for microarthropods in the field is unclear. Following a species sensitivity distribution based on a literature review of four collembola and one worm species 2.7 mg/kg was estimated to be the hazardous concentration for 5% of soil invertebrates.

3.1.2 Bisphenol A

No information about the toxicity of bisphenol A to soil invertebrates was found.

3.1.3 Captan

An abundance of toxicity studies of captan to worms were found of which seven were carried out in accordance to the OECD guideline 207. The majority of the studies used *Eisenia fetida* as test species. The most sensitive, intelligible LC50 value for *Eisenia fetida* was 612 mg/kg. *Lumbricus terrestris* seemed to be more sensitive to captan, with an LC50 of **237 mg/kg**. The chronic NOEC for E. fetida was **50 mg/kg** dry soil. In an experiment with *Aporrectodea caliginosa* 2.8 kg/ha (equivalent to 3.7 mg/kg according to the criteria of scenario II) increased the time to maturity and decreased the number of mature worms in soil cultures, suggesting that the NOEC for other worm species can be lower.

Three beetle species were studied according to GLP on glass plates or in soil. None showed toxic effects at the tested concentrations. Captan was therefore classified as harmless to O*rius insidiosus*, *Pterostichus melanarius* and *Trybliographa rapae* at standard application rates.

Captan was classified as harmless for *Chrysoperla carnae*, *Typhlodromus pyri*, *Aphidius rhopalosiphi* and *Paradosa* sp. at the tested application rates.

A number of studies with soil microorganisms and soil processes exist. The lowest concentration tested was 1 mg/kg, which inhibited N-mineralization by 40% over 14 d and by 6% after 21 d.

Synopsis: Ecotoxicological data were found for oligochaete worms, beetles and other invertebrates. No studies were found for collembola and soil mites. Captan was not toxic to beetles and other invertebrates in the laboratory at the tested concentration. The microorganisms recovered within 21 d.

3.1.4 Chlorpyrifos

A number of toxicity studies of chlorpyrifos on worms exist. The pesticide manual gives a considerable lower LC50 value for *Eisenia fetida* (210 mg/kg) than a detailed OECD study (1077 mg/kg). The most sensitive species in an artificial soil test over 14 d seems to be *Lumbricus rubellus* with an LC50 of **~110 mg/kg**. The chronic NOEC (reproduction) for *Lumbricus rubellus* was **4.6 mg/kg** and for *Eisenia andrei* 49 mg/kg. *Aporrectodea caliginosa* was even more sensitive with a NOEC (growth) < 4 mg/kg.

One species of collembola – *Folsomia candida* – was tested for its sensitivity towards Chlorpyrifos. One test was carried out in artificial soil over 35 d according to an OECD guideline. The LC50 value ranged from 0.2-0.28 mg/kg dry soil depending on the clones tested. The reproduction was not affected at these concentrations. However, in two other studies reproduction of *Folsomia candida* was more sensitive than mortality with a LC50 of **0.13 mg/kg** and a NOEC (reproduction) of **0.05 mg/kg** after exposure in artificial soil over 28 d. In a field bioassay 0.48 kg/ha soil (which corresponds to 0.6 mg/kg according to the criteria of scenario II) were toxic to *Isotoma viridis, Isotomurus palustris, Folsomia candida* and *Sminthurus viridis* (60-80% mortality). At applications of 52.2 and 261 kg/ha in the field decreases in abundance were observed on collembolas and actinedid mites, which got more pronounced with time.

Two laboratory studies for beetles are difficult to interpret as they are expressed per insect or body weight. In a long-term field study a significant reduction in the total adult and larval population of carabids was observed at 0.72 kg/ha with a high total recovery after 10 d. The LR50 and NOEC were not defined.

A study, using *Porcellio scaber*, determined a LC50 of **2 mg/kg** over 5 d. The application rates used in the field study (52.2 and 261 kg/ha), which caused negative effects on collembolas and actinedid mites exceeded by far the registered application rate in Switzerland (0.75 kg/ha).

At 10 mg/kg the total number of bacteria was decreased and the growth and dinitrogen fixation of heterotrophic nitrogen fixers were reduced over 7 d. This resulted in a negative effect on the nitrogen balance of the soil. The observation was terminated after 7 d. In another study with the same concentration the population of bacteria recovered within 3 weeks.

Synopsis: Ecotoxicological data were found for oligochaete worms, collembola, beetles and other invertebrates. Chlorpyrifos caused toxic effects in worms, collembola, beetles, isopods and microorganisms. The microorganisms recovered within 21 d. Collembola seemed to be the most sensitive species.

3.1.5 Cyprodinil

The only LC50 value available for *Eisenia fetida* is **192 mg/kg** determined according to the OECD guideline.

In a field study no negative effects on mite populations were found. Since the application rate is not known, this study cannot be used for the risk assessment.

In two summary statements about the toxicity of cyprodinil, this compound was described as practically non-toxic or harmless to *Poecilus cupreus, Episyrphus* and mites. In another two studies at standard application rates cyprodinil had no effect on *Typhlodromus pyri* and was classified as harmless.

Synopsis: Few studies about the ecotoxicity of cyprodinil to soil organisms were found. Only rudimentary summaries about the toxicity to worms, *Poecilus cupreus, Episyrphus, Typhlodromus pyri* and mites were found. The studies suggested that cyprodinil has a low toxicity to soil invertebrates.

3.1.6 Polychlorinated Dibenzodioxins (PCDD)

Earthworms were unaffected by **5 mg OCDD/kg** over 14 d. A longer exposure time with *Aporrectodea caliginosa* resulted in a NOEC of 5 mg TCDD/kg.

The endpoints for the toxicity of OCDD (octachlorodibenzo-p-dioxin) on collembola lie above the tested maximum concentration of 10 mg/kg. The NOEC is therefore **>10 mg/kg**.

No mortality in carabid beetles was observed at 0.05 mg OCDD/kg, but the feeding rate was reduced by 24%. The endpoints were not determined.

Soil respiration was not affected at concentrations up to 2.4 mg TCDD/kg soil. However, the absence of a negative influence of TCDD (tetrachlorodibenzo-p-dioxin) does not imply that soil mineralization processes are not affected, as the production of carbon dioxide is not a particularly sensitive parameter.

Synopsis: Endpoints for the biological effects of OCDD on earthworms, collembola and carabid beetles were found. No studies were found for soil mites. Worms, collembola, beetles and soil respiration are not acutely sensitive to dioxins based on the available data.

3.1.7 Folpet

Using the OECD guideline test *Lumbricus terrestris* and *Eisenia fetida* showed an LC50 of 459 mg/kg and **339 mg/kg** respectively. No chronic studies were available.

For *Coccinella septempunctata* the reproduction rate was decreased, mortality was not affected. The E value (Beneficial capacity) was 45 and the product was categorised as slightly harmful at standard application rates.

A product was harmless to *Typhlodromus pyri* at a standard application rate.

Synopsis: Ecotoxicological data were found for worms, beetles and other invertebrates. No studies were found for collembola and soil mites. Folpet caused toxic effects in worms and beetles, and was harmless to *Typhlodromus pyri* at the tested concentration.

3.1.8 Iprodione

For earthworms a LC50 **>1000 mg/kg** was determined, whereby the exact species is not known. No chronic studies were available.

No other data for other invertebrate groups were found.

3.1.9 Metolachlor

A LC50 of **140 mg/kg** was determined for earthworms in soil, but the species is not known. No chronic studies were available.

One endpoint for the toxicity of metolachlor for beetles was found for *Menochilus sexmaculatus* with a LC50 of 4726 mg/kg (ppm). However, it is not known how the test compound was tested and what the unit refers to.

The sensitivity of two Braconidae species towards metolachlor was given in a summary with LC50 values of 1406 mg/kg for *Chelonus blackburni* and 2743 mg/kg for *Bracon brevicornis*. However, it is not clear from the summary whether the endpoints refer to the weight of the feed or body weight.

At 3.75 kg/ha no significant effect on the C/N-mineralization was observed.

Synopsis: Three studies with a beetle or wasps are difficult to assess, as the exposure to the test species is not described. Therefore only a study with earthworms was constructive for the assessment. Metolachlor was toxic to worms and had no effect on the C/N-mineralization at the tested concentration.

3.1.10 Polycyclic aromatic hydrocarbons (PAHs)

The toxicity of twelve different PAHs was tested on primarily three worm species. In all tests *Eisenia veneta* was the most sensitive species and *Enchytraeus crypticus* the least. All studies using *Eisenia veneta* were carried out over 28 d in a controlled manner, but not according to any guidelines. The most toxic compounds were fluorene and dibenzofuran with a LC50 (28d) for *Eisenia veneta* of **69 mg/kg** and 78 mg/kg respectively. The least toxic chemical substances for worms seemed to be acridine and naphthalene. For benzo(a)pyrene the NOEC for *Eisenia andrei* is **>100 mg/kg** over 28 d. For chrysene the NOEC for *Eisenia fetida* is given as **1000 mg/kg**. For pyrene the LC50 (28 d) for *Eisenia veneta* is **155 mg/kg**, whereas the NOEC is **18 mg/kg**. For fluoranthene these values for the same species are **416 mg/kg** and **38 mg/kg** respectively.

The toxicity studies with *Folsomia fimetaria* were conducted in a controlled and comprehensible way. Only for phenanthrene *Folsomia candida* was also tested (LC50 144 mg/kg), which seemed less sensitive than *Folsomia fimetaria* towards this compound (LC50 **30 mg/kg**). PAH with reported log K_{ow} 3.3-5.2 (naphthalene, acenaphthene, acenaphthylene, anthracene, phenanthrene, fluorene, pyrene, fluoranthene) significantly affected the survival or reproduction of the test organism *Folsomia fimetaria*. The most toxic compound was dibenzothiophene with a LC50 (21 d) of 21 mg/kg and a NOEC of 8.6 mg/kg. For pyrene these values were **44 mg/kg** and **13 mg/kg** respectively and for fluoranthene **81 mg/kg** and **47 mg/kg**. The least toxic chemical substances were carbazole (LC50 2500 mg/kg), chrysene (LC50 >1030 mg/kg), benzo(a)pyrene (LC50 >840 mg/kg), indeno(1,2,3-cd)pyrene (LC50 >910 mg/kg), dibenz(a,h)anthracene (>780 mg/kg), and benz(a)anthracene (LC50 >980 mg/kg).

The abundance of oribatid mites was negatively affected by small-ring PAH, but not by 5-ring PAH in soil cores. No endpoints were given.

No acute endpoints for the isopods *Porcellio scaber* and *Oniscus asellus* were determined. The NOEC (growth, survival) for both species were **>200 mg/kg** for benz(a)anthracene, fluorene, fluoranthene and phenanthrene. However, for *Oniscus asellus* the NOEC (growth) for fluorene and benz(a)anthracene was one to two orders of magnitude lower (22 and 3 mg/kg). For benzo(a)pyrene the NOEC (growth) varied by an order of magnitude (**10.6 mg/kg** to >106 mg/kg) depending on the duration of observation.

At concentration < 20 mg/kg no effect on nitrification in soil by eight different PAHs was observed.

Synopsis: Studies on the toxicity of fourteen individual PAHs were found for worms, collembola and isopods. Collembola seem to be more sensitive towards PAH than worms or isopods. The order of toxicity of the individual PAH to collembola and worms seems to be similar.

3.1.11 Polychlorinated Biphenyls (PCBs)

For worms the Aroclor mixture 1254 was used. The main congeners in this mixture are: 101, 110, 118, 138. The composition of this mixture is however very variable and exact compositions were not given. The two studies were carried out using filter paper as substrate. *Lumbricus terrestris* reacted more sensitive than *Eisenia fetida*, when the LD50 was assessed. However, the LC50 were 300 $\mu g/cm^2$ (30 kg/ha, 40 mg/kg according to the criteria of scenario II) for *Lumbricus terrestris* and 30.4 $\mu g/cm^2$ (**3.04 kg/ha**, 4 mg/kg according to the criteria of scenario II) for *Eisenia fetida*.

PCB 153 did not cause negative effects on mortality and reproduction of *Folsomia candida* up to **204 mg/kg** soil.

Eight different mixtures of PCB congeners were used for the toxicity studies with two different groups of invertebrates (two insects and one nematode species). The information was taken from a WHO summary and the quoted studies are old and do not seem reliable. The concentrations were expressed per test vessel and therefore cannot be extrapolated. No information was given about the mixture composition. The shells from snails were damaged by 0.5 mg/kg.

The studies with soil microorganisms were conducted in liquid cultures and can therefore not be assessed.

Synopsis: The toxicity studies for worms and insects were carried out using Aroclor mixtures and not single congeners. No data for soil mites, and beetles were found. PCB mixtures were toxic for worms and insects and also damaged the shell of snails at the tested concentrations. PCB 153 was not toxic to collembola at the tested concentrations.

3.1.12 Phthalates

The toxicity of DMP was tested on four different earthworm species in artificial soil according to the OECD guideline. The LC50 values ranged from 1064-3335 mg/kg, with *Eisenia fetida* being one of the less sensitive species. Out of five phthalates tested in a contact filter paper test DMP seemed the most toxic to *Eisenia fetida* and more toxic in the contact filter paper test (LC50 550 $\mu g/cm^2$ = 55 kg/ha $\cong$ 70 mg/kg according to the criteria of scenario II) than in the artificial soil test (LC50 3160 mg/kg). DEHP showed the lowest toxicity with a LC50 **> 2500 kg/ha**.

The only collembola species tested was *Folsomia fimetaria* with sandy soil as substrate. DEHP was not toxic to adults and juveniles of the species with NOEC >5000 mg/kg and **>1000 mg/kg** respectively. Neither survival nor reproduction was affected. For DBP a controlled study was found, yet it showed great variability within the data. The reproduction of adults was more sensitive than their survival. For DBP the LC50 for adults was 277 mg/kg. All juveniles died within 1 d at 25 mg/kg. The LC50 for juveniles was **19.4 mg/kg** and the NOEC **<1 mg/kg**.

The NOEL of 17 phthalates was >20 μg/insect, which was equivalent to 1000 mg/kg body weight.

100 mg/kg of DEP or DEHP had no impact on the structural diversity or functional diversity of the microbial community in soil over 28 d. However, at concentrations >1000 mg DEP/kg the numbers of total culturable bacteria and pseudomonads were reduced for 16 d. DEHP at 100’000 mg/kg had no impact on the microbial community.

Synopsis: Ecotoxicity studies were mainly carried out using DBP (dibutyl phthalate) or DEHP (di(2-ethylhexyl) phthalate). Furthermore, good studies with DMP (dimethyl phthalate) exist for worms.

DMP seems to be the most toxic followed by DBP, with DEHP being the least toxic phthalate. Juvenile collembola were more sensitive than adults or worms.

3.1.13 Polybrominated diphenylethers (PBDEs)

Only data about the toicity of MBDE (monobromodiphenylether) to aquatic organisms were found. MBDE is classified as toxic to strongly toxic to aquatic organisms.

3.1.14 Procymidone

No information about th toxicity of procymidone to soil invertebrates was found.

3.1.15 Thiabendazole

The LC50 for worms is **>500 mg/kg** and the NOEC (reproduction) is **4.2 mg/kg**.

Thiabendazole is harmless to *Aleochara bilineata*, *Chrysoperla carnea* and *Typhlodromus pyri* at application rates of 0.9 kg/ha and 1.8 kg/ha respectively for the latter two. There is a slight hazard for *Aphidius rhopalosiphi* at an application rate of 1.8 kg/ha resulting in a 62% decrease in fecundity.

At a dose of 9 mg/kg no significant effects on C/N-mineralization were observed.

Synopsis: Only rudmentary summaries were found about the toxicity of thiabendazole to worms and other invertebrates. No studies were found for collembola, soil mites and beetles. Thiabendazole has a low acute toxicity to worms, is harmless to slightly toxic to other invertebrates and has no effect on the C/N-mineralization at the tested concentrations.

3.1.16 Trifluralin

The LC50 of *Eisenia fetida* is **>1000 mg/kg** over 14 d. However, already at 100 mg/kg toxic effects on earthworms were observed.

An uptake and a toxicity (diet) study of Elancolan with *P. scaber* was found. However, as the concentration of trifluralin in Elancolan was not known, it was not possible to assess this ecotoxicological study.

1 mg/kg soil significantly affected the bacterial populations in the rhizosphere. However, the effect declined with time over a four-week period of monitoring.

Synopsis: Very few studies about the ecotoxicity of trifluralin to oligochaete worms, other invertebrates and microorganisms were found. No studies were available for collembola, soil mites and beetles. Trifluralin has a low acute toxicity to worms and its effect on the bacterial population is reversible.

3.1.17 Vinclozolin

The LC50 for *Tubifex tubifex* is **520 mg/kg**. No studies with *Eisenia fetida* were found.

One study with *Adalia bipunctata* was found, but is difficult to assess for several reasons. 1) immersion tests are difficult to relate to more realistic conditions 2) no control data was given.

Negative effects on bacteria, fungi, actinomycets and urea hydrolysis occurred at 10 mg/kg in soil samples from rice fields over 56 d. A recovery was not apparent.

Synopsis: An unsatisfactory amount and quality of studies were found for worms, beetles and microorganisms. No studies at all were found for collembola or soil mites. Vinclozolin was toxic to worms and microorganisms at the tested concentration.

3.2 Exposure

Worst-case concentrations of chemical substances in compost were derived from measured and estimated concentrations (Table 3). The concentrations of the ubiquitous chemical substances in compost, apart from bisphenol A and PBDEs, were measured in Swiss, Austrian, German, Swedish or Brazilian compost and taken from literature. For the pesticides captan, cyprodinil, folpet, metolachlor and procymidon no data concerning their concentration in compost could be found. Their concentrations were therefore estimated based on the maximum residue levels on crops, which are defined in the Swiss Ordinance on Foreign Substances and Components (FIV). These maximum residue levels are not reached if farmers follow the rules of good agricultural practice (GAP[1]). Cantonal laboratories regularly control residues in food on the Swiss market. The concentrations estimated from the maximum residue levels are expected to be a very stable first estimate for worst-case concentrations in the compost and higher than the available measured concentrations in compost. Only for atrazine the measured concentration in American compost was three times greater than the estimated concentration based on the Swiss FIV data. The measured pesticide concentrations in compost are derived from few measurements and insufficient information is available to assess in how far these values are representative for Swiss compost. The concentrations estimated from the FIV data were used as worst-case concentrations for this risk assessment as no realistic concentrations were available for Swiss compost. PEC for scenarios I to V are given in Annex II.

Table 3: Concentrations of the chemical substances in biogenic waste used in the risk assessment. The references are given in the following text.

	Concentration [mg/kg dw]	
Chemical substance	Measured	Estimated based on FIV data
Atrazine	3.03	1
Bisphenol A		
Captan		30
Chlorpyrifos	0.008	5
Cyprodinil		30
PCDD/PCDF (in OCDD-TEQ)	0.006	
Folpet		30
Iprodione	0.04	50
Metolachlor		0.5
PAH (individual compounds)	0.001-0.358	
PCB (sum of congeners)	0.01-0.1	
Phthalate DBP	0.09	
DEHP	0.2	
PBDEs		
Procymidon		50
Thiabendazole	0.03	50
Trifluralin	0.156	0.5
Vinclozolin	0.2	10

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[1] The nationally recommended, authorised or registered safe use of pesticides for effective and reliable pest control under consideration of public and occupational health as well as the environment.

3.2.1 Atrazine

The worst-case concentration of atrazine in compost based on the FIV data for corn (0.1 mg/kg ww) is three times lower than the measured concentration in American compost (3.03 mg/kg dw). The study was conducted in Illinois and tested finished compost from eleven landscape composting facilities over four seasons. In one sample of the raw yard trimmings the atrazine concentration exceeded the Maximum Allowable Tolerance for Raw Agricultural Commodities (MAT) for hay crops in America (15 mg/kg) (Büyüksönmez et al., 2000).

3.2.2 Bisphenol A

The concentration of bisphenol A in compost is unknown at present.

3.2.3 Captan

Captan has not been measured in composts so far. The concentration was estimated based on the FIV data for aubergines, fruit and tomatoes (3 mg/kg ww).

3.2.4 Chlorpyrifos

The worst-case concentration of chlorpyrifos in compost based on the FIV data for aubergines, pepper, pip fruit, tomatoes and grapes (0.5 mg/kg ww) is over six hundred times greater than the measured concentration in American compost (0.008 mg/kg dw). The study was conducted in Illinois and tested finished compost from eleven landscape composting facilities over four seasons (Büyüksönmez et al., 2000). The Maximum Allowable Tolerance for Raw Agricultural Commodities (MAT) for hay crops in America is 15 mg chlorpyrifos/kg.

3.2.5 Cyprodinil

Cyprodinil has not been measured in compost so far. The concentration was estimated based on the FIV data for salad and grapes (3 mg/kg ww).

3.2.6 Polychlorinated Dibenzodioxins (PCDD)

The concentration of PCDD and PCDF in domestic garden compost was taken from an Austrian study (0.000’006 mg I-TEQ/kg[2]) (Zethner et al., 2001). In compost from Brazil an average of 0.000’042 mg I-TEQ/kg was detected (Grossi et al., 1998), whereas in Germany a guide value for compost of 0.000’017 mg I-TEQ/kg is given. The toxic equivalency factor (TEF) for 2,3,7,8-TCDD is 1 and for OCDD 0.001 (Safe 1997). The concentration of PCDD and PCDF expressed in OCDD-TEQ is therefore 0.006 mg/kg.

3.2.7 Folpet

Folpet has not been determined in compost so far. The concentration was estimated based on FIV data for aubergines, fruit and tomatoes (3 mg/kg ww).

3.2.8 Iprodione

The worst-case concentration of iprodione in compost based on the FIV data for aubergine, berries, peppers, garlic, cabbage, tomatoes and onions (5 mg/kg ww) is over a thousand times greater than the measured concentration in Italian compost (0.04 mg/kg dw). Iprodione was detected in one out of five Italian commercial compost samples (Vanni et al., 2000).

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[2] I-TEQ: International Toxic Equivalents

3.2.9 Metolachlor

Metolachlor has not been determined in compost so far. The concentration was estimated based on the FIV data for beans, pumpkin seeds, corn, soya beans, sunflower seeds and sugar roots (0.05 mg/kg ww).

3.2.10 Polycyclic aromatic hydrocarbons (PAHs)

A range of individual PAHs have been measured in compost from Austria (Zethner et al., 2001) and Switzerland (Berset et al., 1995). The concentrations of the individual congeners are two to five times greater in the Swiss compost (0.001-0.358 mg/kg) compared to Austrian compost (0.0066-0.148 mg/kg). The sum of sixteen PAHs had a median of 2.5 mg/kg in Swiss compost and of 0.9 mg/kg in Austrian compost.

3.2.11 Polychlorinated Biphenyls (PCBs)

The concentration of PCB was measured in compost from Austria (Zethner et al., 2001), Switzerland (Berset et al., 1995) and Sweden (Wagman et al., 1999). The individual congeners as well as groups of congeners were determined. As all ecotoxicity studies were carried out with mixtures of congeners, the toxicity data could only be related to the total measured PCB concentration. Concentrations differed by an order of magnitude from 0.01-0.1 mg/kg.

3.2.12 Phthalates

The concentration of DBP and DEHP was measured in nine composts from Germany (Hund et al., 1999). The average concentration of DBP in the finished compost was 0.09 mg/kg and of DEHP 0.2 mg/kg. No information about the concentration of DMP in compost was found.

3.2.13 Polybrominated diphenylethers (PBDEs)

The concentration of PBDEs in compost is unknown at present.

3.2.14 Procymidone

Procymidone has not been measured in compost so far. The concentration was estimated based on the FIV data for soft fruit and salad (5 mg/kg ww).

3.2.15 Thiabendazole

The worst-case concentration of Thiabendazole in compost based on the FIV data for broccoli, strawberries and pip fruit (5 mg/kg ww) is over a thousand times greater than the measured concentration in German compost (0.03 mg/kg dw) (Hund et al., 1999).

3.2.16 Trifluralin

The worst-case concentration of trifluralin in compost based on the FIV data for peas, grains, cabbage, rapeseed and tomatoes (0.05 mg/kg ww) is three times greater than the measured concentration in American compost (0.156 mg/kg dw). The study was conducted in Illinois and tested finished compost from eleven landscape composting facilities over four seasons. The concentration in the raw yard trimmings (0.142 mg/kg dw) was slightly lower than in the finished compost, which suggests that composting concentrated trifluralin (Büyüksönmez et al., 2000).

3.2.17 Vinclozolin

The worst-case concentration of vinclozolin in compost based on the FIV data for soft fruit and salad (1 mg/kg ww) is fifty times greater than the measured concentration in Italian compost (0.2 mg/kg dw). Vinclozolin was detected in one out of five Italian commercial compost samples (Vanni et al., 2000).

3.3 Risk Assessment

3.3.1 Atrazine

As atrazine can potentially be persistent in soil (DT50 5-119 d) the long-term endpoints were used for the assessment (Table 4). The quality and quantity of data were such that the trigger values from the EU could be used (assessment level I) for worms, collembola and beetles. As no detailed description of the study with microarthropods was available, the study had to be classified as level II.

Table 4: Factors by which long-term indicators (TER, HQ) exceed the appropriate trigger values based on the FIV data. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	I	I	-	I	II
Scenario I	6	0.6	-		
Scenario II	48	4	-	50’000	40’000
Scenario III	192	15	-		
Scenario IV	480	38	-	500’000	400’000
Scenario V	1’920	150	-		

The estimated worst-case concentration of atrazine in compost does not pose a long-term risk to worms, beetles and other invertebrates in any usage scenarios. Collembola living directly in the compost are at a long-term risk (scenario I). The short-term risk is lower than the long-term risk for worms and collembola. If the measured concentration of atrazine in American compost was used, an unacceptable short-term and long-term risk for collembola could exist in scenario I. No data were found for soil mites. In two field studies the effect on microarthropods (including mites) was quite different, which could be a result of the adaptation in previously treated fields.

At the predicted (measured or estimated) concentration no effect on the N-mineralization is expected.

The application of compost as soil improver and fertilizer does not cause an ecotoxicological risk to soil organisms provided that the compost only contains atrazine up to levels achieved under good agricultural practise. In compost used undiluted as growth substrate for plants a potential risk to collembola exists.

3.3.2 Bisphenol A

As no information about the toxicity of bisphenol A to soil invertebrates is present no risk assessment for this compound could be carried out.

3.3.3 Captan

As captan is rapidly degraded (DT50 1-10 d) the short-term endpoints were used for the assessment (Table 5). The quality and quantity of data were such that the trigger values from the EU could be used (assessment level I) for worms, beetles and other invertebrates.

Table 5: Factors by which short-term indicators (TER) exceed the appropriate trigger values based on the FIV data. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	I	-	-	-	-
Scenario I	0.8	-	-	-	-
Scenario II	6	-	-	-	-
Scenario III	24	-	-	-	-
Scenario IV	59	-	-	-	-
Scenario V	237	-	-	-	-

The estimated worst-case concentration of captan in compost does not pose a short-term risk to worms, when the compost is worked into the soil (scenarios II-V). Directly in the compost, worms are exposed to an unacceptable risk. The long-term risk is not known. Beetles showed no effect at the PECs. Other invertebrates (*Typhlodromus pyri*) were tested at a concentration below the worst-case PEC, whereby no negative effects were observed. It is therefore not possible to reliably assess the risk to other invertebrates at the predicted concentration. No data was found for collembola and soil mites.

At a concentration of 1 mg/kg, nitrification in the soil was reduced by 6% after 21 d. According Annex VI of 91/414/EEC this small and reversible effect is classified as harmless.

The application of compost as soil improver and fertilizer does not cause an ecotoxicological risk to worms and beetles provided that the compost only contains captan up to the levels achieved under good agricultural practise. In compost used undiluted as growth substrate for plants a risk to worms cannot be excluded. An assessment for collembola, soil mites and other invertebrates was not possible.

3.3.4 Chlorpyrifos

As chlorpyrifos can potentially be persistent in soil (DT50 11-141 d) the long-term endpoints were primarily used for the assessment (Table 6). The quality and quantity of data were such that the trigger values from the EU could be used (assessment level I) for worms and collembola. The assessment for other invertebrates had to be carried out on level III, as only one isopoda species was tested, not according to a guideline.

Table 6: Factors by which long-term indicators (TER) exceed the appropriate trigger values based on the FIV data. For the assessment of other invertebrates only a short-term endpoint was available. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	I	I	-	-	III
Scenario I	0.2	0.002	-	-	0.0004
Scenario II	1.4	0.02	-	-	0.003
Scenario III	6	0.06	-	-	0.01
Scenario IV	14	0.2	-	-	0.03
Scenario V	55	0.6	-	-	0.1

The estimated worst-case concentration of chlorpyrifos in compost does not pose a long-term risk for *Lumbricus rubellus* in the usage scenarios II-V. Directly in the compost, an unacceptable risk to worms might exist. Since the short-term risk to worms is lower and acceptable, the overall risk depends on the degradation rate of Chlorpyrifos in compost. Collembola and isopods are at an unacceptable short- and long-term risk in all scenarios. If the measured concentration of Chlorpyrifos in American compost was used, no short- and long-term risk exists for worms, collembola and isopoda by the application of compost. No data were available for soil mites. Furthermore, no trustworthy endpoint studies were found for beetles.

Soil processes and microorganisms were tested at a concentration greatly exceeding the predicted concentrations. In these studies a decrease in dinitrogen fixing bacteria was observed over 7 d. Nitrification, total number of bacteria and fungal population were not significantly affected in the long-term. It is therefore not expected that chlorpyrifos poses a risk for soil processes in any scenario.

If a risk to worms, collembolan and isopods by the application of compost containing crops treated with chlorpyrifos is to be excluded, the residues on crops have to be below the maximum residue level. Concentrations in American compost were far below the level estimated on the FIV-data and worms, collembola and isopods would not be at risk.

3.3.5 Cyprodinil

Cyprodinil is not described as being persistent in the soil (DT50 20-60 d). Therefore the short-term risks are assessed initially. As only one summary endpoint according to OECD guideline was found for worms the assessment is carried out on level II (Table 7).

Table 7: Factors by which short-term indicator (TER) exceed the appropriate trigger value based on the FIV data. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	II	-	-	-	-
Scenario I	0.06	-	-	-	-
Scenario II	0.5	-	-	-	-
Scenario III	2	-	-	-	-
Scenario IV	5	-	-	-	-
Scenario V	19	-	-	-	-

Worms are at risk in scenario I and II if the PEC is calculated with estimated worst-case concentration. No long-term studies and NOEC were available to assess the long-term risk to worms. Other invertebrates (*Typhlodromus pyri*) were tested at a concentration below the worst-case PEC, whereby no negative effects were observed. It is therefore not possible to reliably assess the risk to other invertebrates at the predicted concentration. No data were available for collembola, soil mites and beetles.

In compost used undiluted as growth medium for plants worms could be at a short-term risk. Even if composts are used as soil improver worms may be at risk. No assessment can be made for collembola, soil mites, beetles, other invertebrates and soil microorganisms. Ecotoxicological and exposure information is therefore too rudimentary to make a reliable risk assessment for cyprodinil.

3.3.6 Polychlorinated Dibenzodioxins (PCDD)

Dioxins are very persistent in soil (DT50 1-10 a), therefore the long-term risk was assessed. Endpoints for earthworms and collembola exist for OCDD, but only the concentration of the sum of PCDD in compost in I-TEQ was available. Therefore the concentration was converted in OCDD-TEQ based on the toxic equivalency factor for vertebrates as defined by Safe (1997). As only rudimentary summaries were available for the sensitivity of worms and collembola the assessments were carried out on level II (Table 8).

Table 8: Factors by which long-term indicators (TER) exceed the appropriate trigger values. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	II	II	-	-	-
Scenario I	7	33	-	-	-
Scenario II	125	250	-	-	-
Scenario III	500	1’000	-	-	-
Scenario IV	1’250	2’500	-	-	-
Scenario V	5’000	10’000	-	-	-

Worms and collembola are not at risk by the application of compost in any usage scenario. The NOEC was not determined for beetles and therefore no TER could be calculated. The concentration which caused a 24% reduction in feeding rate in beetles, but no mortality was ten times greater than the measured concentration in garden compost. A risk to beetles by the application of compost is therefore considered to be low. Furthermore no effect of TCDD on soil respiration was observed at the predicted concentration of TCDD in any scenario.

With the limited data available it is assumed that the risk of PCDD in compost to soil organisms and microorganisms is small. As PCDD exert their toxic actions mainly through interactions with a specific receptor (Ah-receptor), which is not synthesized in invertebrates, ecotoxic effects to soil organisms are at present hardly conceivable. However, due to the high bioaccumulation and persistency of dioxins in soil the occurrence of these substances in the environment should be carefully monitored.

3.3.7 Folpet

As folpet is rapidly degraded (DT50 4.3 d), the short-term endpoints are used for the assessment (Table 9). The quality and quantity of data were such that the trigger values from the EU could be used (assessment level I) for worms.

Table 9: Factors by which short-term indicator (TER) exceed the appropriate trigger value based on the FIV data. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	I	-	-	-	-
Scenario I	1.1	-	-	-	-
Scenario II	9	-	-	-	-
Scenario III	34	-	-	-	-
Scenario IV	85	-	-	-	-
Scenario V	339	-	-	-	-

The estimated worst-case concentration of folpet in compost does not pose a risk to worms in any usage scenario. For beetles and *Typhlodromus pyri* no endpoint was determined and therefore no TER could be calculated. The concentration which caused an effect on the fertility of the ladybird beetle over several weeks was comparable to the PEC based on the estimated worst-case concentration with both application rates. Therefore a certain risk to beetles cannot be excluded at present, even though it is considered to be low due to the fast degradation of folpet in soil. The same concentration was harmless to *Typhlodromus pyri*. No effects on mortality and reproduction were observed. However, as *Typhlodromus pyri* is not a soil organism it cannot be taken as a representative species for soil invertebrates. No data was found for collembola and soil mites.

The application of compost as fertilizer, soil improver and growth medium for plants does not cause an ecotoxicological risk to worms provided that the compost only contains folpet up to levels achieved under good agricultural practise. Risks to collembola, soil mites, beetles and other invertebrates seem improbable due to the rapid degradation, but cannot be safely excluded due to a lack of relevant studies.

3.3.8 Iprodione

As iprodione is potentially persistent in soil (DT50 20-160 d), short- and long-term risks should be assessed. However, insufficient data for a complete risk assessment for iprodione was found. Due to the poor quality and lack of data the risk assessment could only be carried out for worms at level III (Table 10).

Table 10: Factors by which short-term indicator (TER) exceed the appropriate trigger value based on the FIV data. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	III	-	-	-	-
Scenario I	0.02	-	-	-	-
Scenario II	0.15	-	-	-	-
Scenario III	0.6	-	-	-	-
Scenario IV	1.5	-	-	-	-
Scenario V	6	-	-	-	-

The estimated worst-case concentration of iprodione in compost does potentially pose a short-term risk to worms in scenario I-III. Because of the persistency in soil the long-term risk should be assessed. However, no long-term studies were available. If the measured concentration of iprodione in Italian compost was used, no short-term risk exists for worms. No data were available for collembola, soil mites, beetles and other invertebrates.

Due to the lack of long-term studies with this persistent fungicide the risk could not be assessed satisfactorily. Based on the available information the short-term risk of iprodione in compost used as fertilizer is expected to be low to worms. However, in order to give a more accurate risk assessment further and more detailed ecotoxicity studies are needed.

3.3.9 Metolachlor

As metolachlor is not persistent in soil (DT50 14-51 d) short-term studies were used for the assessment. Only rudimentary summaries were available for one worm and one beetle species, and for two Braconidae species. However, the units for the exposure concentrations were unclear for the beetle and Braconidae. For worms the quality of the study lead to an assessment level III.

Table 11: Factors by which short-term indicator (TER) exceed the appropriate trigger value based on the FIV data. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	III	-	-	-	-
Scenario I	0.28	-	-	-	-
Scenario II	2	-	-	-	-
Scenario III	8	-	-	-	-
Scenario IV	21	-	-	-	-
Scenario V	84	-	-	-	-

The estimated worst-case concentration of metolachlor in compost does not pose a short-term risk to worms in scenarios II-V. Worms living directly in the compost will be at risk. The long-term risk could not be assessed. No data was available for collembola, soil mites, beetles and other invertebrates.

At a seventy five times greater application rate than the one corresponding to 100 t compost/ha no significant effect on the C/N-mineralization was observed.

The application of compost as soil improver and fertilizer is unlikely to cause an ecotoxicological risk to worms and microorganisms provided that the compost only contains metolachlor up to levels achieved under good agricultural practise. In compost used undiluted as growth medium for plants a risk to worms cannot be excluded. However, in order to give a more accurate risk assessment further and more detailed studies on the acute ecotoxicity and concentration in compost are needed.

3.3.10 Polycyclic aromatic hydrocarbons (PAHs)

Some PAHs are persistent, whereas others are readily degraded (DT50 >200 d or 16-60 d). The individual PAH differ in their toxicity to soil organisms. However, the differences were minor and the individual compounds are thus discussed as one apart from a few exception. The quality and quantity of data were such that the trigger values from the EU could be used (assessment level I) for worms, collembola and other invertebrates.

Table 12: Factors by which long-term indicators (TER) exceed the appropriate trigger values. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	I	I	-	-	I
Scenario I	13-2’247	9-23’636	-	-	3-887
Scenario II	95-16’854	69-177’273	-	-	23-6’651
Scenario III	382-67’416	276-709’091	-	-	92-26’604
Scenario IV	954-168’539	689-1’772’727	-	-	231-66’509
Scenario V	3’816-674’157	2’756-7'090’909	-	-	923-266’038

Worms are not at an unacceptable long-term risk in any scenario by benzo(a)pyrene, chrysen, fluorene, fluoranthene, phenanthrene, and pyrene. The short-term risk is even lower.

Collembola are also not at an unacceptable short-term risk in any scenario by acenaphten, acenaphtylen, anthracene, fluorene, fluoranthene, phenanthrene, and pyrene. Furthermore long-term risks by benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysen, dibenz(a,h)anthracene, fluorene, fluoranthene, indeno(1,2,3-cd)pyrene, and phenanthrene can be excluded.

Isopods are also not at a long-term risk by benz(a)anthracene, benzo(a)pyrene, fluorene, fluoranthene, and phenanthrene.

Therefore sufficient data is available to exclude a short- and long-term risk to soil organisms by the application of compost containing PAH as fertilizer, soil improver and growth substrate for plants.

3.3.11 Polychlorinated Biphenyls (PCBs)

PCBs are persistent in the soil and thus the long-term effects have to be assessed. For worms only short-term filter paper studies existed, which simulate the exposure by body contact. The effect of adsorption of the compound in the soil as well as the oral uptake of the compound cannot be assessed by this test set-up. Therefore the assessment was carried out on level III (Table 13). For collembola one no-effect study according to an ISO protocol was available. Due to the quality of the data the assessment was carried out on level I.

Table 13: Factors by which short-term indicators (TER, HQ) exceed the appropriate trigger values. The highest measured PCB concentration in compost was used. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	III	I	-	-	-
Scenario I		3’138	-	-	-
Scenario II	7	23’538	-	-	-
Scenario III		94’154	-	-	-
Scenario IV	67	235’385	-	-	-
Scenario V		941’538	-	-	-

Worms and collembola are not at risk by the application of PCBs in compost at either application rate. No long-term studies were obtainable for worms. PCBs have a lethal effect on *Drosophila melanogaster* and sublethal effects on *Acrobeloides nanus*, but the units of the endpoints were difficult to assess. No data was available for collembola, soil mites and beetles.

With the limited data available it is assumed that the risk of PCBs in compost to soil organisms is small. Modes of action in vertebrates include the interaction with the Ah-receptor for coplanar PCBs and the interference of signal transduction pathways with possible effects on the nervous system for non-coplanar PCBs. Effects on invertebrates by the same modes of action are not expected. However, due to the high bioaccumulation and persistency of PCBs in soil the occurrence of these substances in the environment should be carefully monitored.

3.3.12 Phthalates

The degradation rates differ for phthalates and definite DT50 are hard to find. Therefore long-term risks were assessed for DBP (Table 14) and for DEHP (Table 15). The toxicity of DBP, DEHP and DEP was tested on worms, collembola and beetles, but the concentration of DEP in compost is not known. The study for worms was carried out with filter paper and is not representative for the exposure in soil or compost. The assessment was therefore carried out on level II. Only one collembola species was tested in sandy soil, therefore the risk was assessed on level II.

Worms are not at a short- or long-term risk from DEHP in compost; yet it was also the least toxic of a range of phthalates tested in the filter paper test. Collembola are not at long-term risk by DEHP in any scenario, but by DBP in scenario I. However, no short-term risks by DBP exist for collembola living in the compost. The overall assessment therefore depends on the degradation of phthalates in compost. No data on soil mites, beetles and other invertebrates was available.

Table 14: Factors by which long-term indicator (TER) exceed the appropriate trigger value for DBP. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	-	II	-	-	-
Scenario I	-	0.2	-	-	-
Scenario II	-	1.7	-	-	-
Scenario III	-	7.0	-	-	-
Scenario IV	-	17	-	-	-
Scenario V	-	67	-	-	-

Table 15: Factors by which long-term indicators (TER, HQ) exceed the appropriate trigger values for DEHP. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	II	II	-	-	-
Scenario I		100	-	-	-
Scenario II	20’000	750	-	-	-
Scenario III		3’000	-	-	-
Scenario IV	200’000	7’500	-	-	-
Scenario V		30’000	-	-	-

At the predicted concentrations in the field no significant impact on the soil community is expected.

The application of compost as fertilizer is unlikely to cause an ecotoxicological risk to worms, collembola and microorganisms provided that the compost only contains phthalates up to the extrapolated levels. In compost used undiluted as growth medium for plants collembola are at a long-term risk. Since not the most toxic phthalates were investigated, nor data about the degradation rate in compost or toxicity towards soil mites, beetles and other invertebrates was available, risks cannot be fully excluded.

3.3.13 Polybrominated diphenylethers (PBDEs)

As no information about the toxicity of PBDEs to soil invertebrates is present no risk assessment for this compound could be carried out.

3.3.14 Procymidone

As no information about the toxicity of procymidone to soil invertebrates is present no risk assessment for this compound could be carried out.

3.3.15 Thiabendazole

As thiabendazole is potentially persistent in soil (DT50 33-120 d) the long-term risk has to be assessed. Only rudimentary summaries were available for worms, therefore the assessment was carried out on level II.

Table 16: Factors by which long-term indicator (TER) exceed the appropriate trigger value based on the FIV data. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	II	-	-	-	-
Scenario I	0.002	-	-	-	-
Scenario II	0.01	-	-	-	-
Scenario III	0.06	-	-	-	-
Scenario IV	0.1	-	-	-	-
Scenario V	0.5	-	-	-	-

The estimated worst-case concentration of thiabendazole in compost does potentially pose a long-term risk to worms in all scenarios. Short-term risks exist also in scenario I and II. *Aleochara bilineata*, *Chrysoperla carnea* and *Typhlodromus pyri* are not expected to be at risk by the application of 10 t compost/ha. A higher application rate was not tested and can therefore not be assessed. *Aphidius rhopalosiphi* might be at a long-term risk by the application of 100 t compost/ha (5 kg thiabendazole/ha) as the application of 1.8 kg thiabendazole/ha decreased the fecundity by 62%. No data for collembola, soil mites and beetles were available.

The concentration at which no significant effects on the C/N-mineralization were observed was comparable to the predicted worst-case concentration.

The application of compost as fertilizer, soil improver or as growth substrate causes a long-term risks to worms and other invertebrates if the compost contains thiabendazole up to the levels achieved by good agricultural practise. The use as soil improver or growth substrate may also cause a short-term risk to worms. Based on the measured concentration in Austrian compost no risk to worms and other invertebrates is expected in any scenario. Soil microorganisms are not at risk in any scenario at either concentration. The risk to collembola, soil mites and beetles could not be assessed.

3.3.16 Trifluralin

Trifluralin is potentially persistent in soil (DT50 up to 8 months). Therefore the long-term studies are important for the assessment. As only one rudimentary short-term summary was available for *Eisenia fetida,* the assessment was carried out on level III.

The estimated worst-case concentration of trifluralin in compost does not pose a short-term risk to worms in any scenario. The long-term risk could not be assessed. No data was available for collembola, soil mites, beetles and other invertebrates.

The lowest tested concentration, which showed significant effects on the population of soil rhizosphere was about ten times greater than the predicted worst-case concentration. The effects were reversible as the bacteria population recovered over four weeks.

Based on the available knowledge no risks to worms or soil microorganisms is expected by the application of compost as growth substrate, soil improver or fertilizer containing trifluralin up to levels achieved under good agricultural practise or comparable to the American compost. The risk to collembola, soil mites and beetles could not be assessed.

Table 17 Factors by which short-term indicator (TER) exceed the appropriate trigger value based on the FIV data. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	III	-	-	-	-
Scenario I	2	-	-	-	-
Scenario II	15	-	-	-	-
Scenario III	60	-	-	-	-
Scenario IV	150	-	-	-	-
Scenario V	600	-	-	-	-

3.3.17 Vinclozolin

Vinclozolin is potentially persistent in the soil (DT50 several weeks). Therefore the long-term risks should be assessed. As there was only one study available with *Tubifex tubifex*, which is not a representative species for the compost environment, the assessment was carried out on level III (Table 18).

Table 18 Factors by which short-term indicator (TER) exceed the appropriate trigger value based on the FIV data. Assessment levels are defined in Table 2.

	Worms	Collembola	Soil mites	Beetles	Others
Assessment level	III	-	-	-	-
Scenario I	0.05	-	-	-	-
Scenario II	0.4	-	-	-	-
Scenario III	1.5	-	-	-	-
Scenario IV	3.9	-	-	-	-
Scenario V	16	-	-	-	-

The estimated worst-case concentration of vinclozolin in compost does potentially pose a short-term risk to worms in scenario I and II. The long-term risk cannot be assessed. No data was available for collembola, soil mites, beetles and other invertebrates.

The lowest tested concentration, which showed negative effects on soil microorganisms was ten times greater than the predicted worst-case concentration. A recovery was not apparent over eight weeks.

The application of compost as soil improver or as growth substrate causes an ecotoxicological risk to worms and possibly to soil microorganisms if the compost contains vinclozolin up to the levels achieved by good agricultural practise. Based on the measured concentration in Italian compost no risk to worms is expected by any usage. The risk to collembola, soil mites, beetles and other invertebrates could not be assessed.

4. Conclusions

The overall risk assessment for the seventeen selected chemical substances showed that risks generally decreased in the order of undiluted compost > soil improver > soil fertilizer. For some chemical substances risks to soil organisms by the recycling of compost in agriculture are generally acceptable (Table 19). This means, that compost containing PCDD, PAH or PCB up to the levels assumed in this risk assessment can be recycled in agriculture. In addition, the presence of atrazine and captan does not impose a limit to the application of compost into agricultural soil according to current knowledge. However, should the concentration of atrazine in Swiss compost be comparable to American compost the usage of compost as growth substrate would not be recommended. For other chemical substances risks are uncertain and more information on their ecotoxiciological effects or concentration in Swiss compost are needed to fully evaluate their impact on the soil community. For bisphenol A, PBDE and procymidone no risk assessment at all could be made.

Great gaps became apparent in the terrestrial (soil) ecotoxicology of the chemical substances (Table 20). Studies with birds and aquatic species were more abundant. However, soil organisms (besides microorganisms) are mostly invertebrates with a physiology, life form and behaviour, which differ very much from that of vertebrates. For example, endocrine disruptors often exert their effects in vertebrates by binding to estrogen and androgen receptors. However, in invertebrates modes of action are just being discovered. Therefore, an extrapolation of toxicological sensitivity from vertebrates to invertebrates is difficult.

Further significant gaps exist in the knowledge about the concentration of the chemical substances in compost. The concentrations of pesticides had to be estimated based on maximum residue levels on crops. Even if measured concentrations in compost were available, they were not necessarily representative for Swiss compost or the origin and composition of the compost was not known. It seems probable, that FIV-based concentrations of pesticides in compost are a significant overestimation of real concentrations in Swiss compost. For three out of six pesticides the measured concentrations were several hundred times lower than the FIV-based concentrations; for two the measured concentrations were lower by a factor of fifty resp. three. For one pesticide the measured concentration was three times greater than the FIV-based concentration. Module 4 and subsequent will deliver a better knowledge of representative concentrations of chemical substances in Swiss compost.

To come to a reliable risk assessment about the use of compost recycling in agriculture the following topics should be addressed:

1. Detailed information on ecotoxicological effects of the chemical substances
   - To improve the risk assessment, i.e., to make it more realistic, more detailed information on the ecotoxicity is needed. The two weak points regarding ecotoxicology in the current risk assessment are:
     - Only one or two organism groups per chemical substance have been tested (mainly worms, sometimes collembola); sometimes no test at all has been performed.
     - Long-term studies for persistent chemical substances do not always exist.
   - In order to perform a sound risk assessment for the soil ecosystem, with its wide range of organisms, organism groups, food chains, and important functions for ecosystems, several different species have to be investigated. For persistent chemical substances long-term studies are of special relevance.

2. Concentrations of the chemical substances in Swiss compost
   - In order to fully evaluate the risk to soil organisms by the application of compost it is crucial that a better knowledge of the predicted environmental concentrations in Swiss compost is gained. For pesticides, quality standards or concentration measurements should guarantee that concentrations of pesticides in the organic materials used for composting do not surmount maximum residue levels defined in the FIV. Residues in agricultural crops are already very well surveyed by the Swiss cantonal laboratories. Evidence that concentrations of pesticides in compost are greatly below the maximum residue levels defined in the FIV would significantly increase the certainty that ecotoxicological risks are acceptable. Reliable methods to demonstrate this include:
     - The measurement of dissipation times of pesticides during composting.
     - The chemical analysis of concentrations in different finished Swiss composts.
   - In the case of the halogenated organic substances a monitoring to confirm the trend of decreasing environmental concentrations would be useful to assure that these persistent chemical substances do not become a problem in the future.

To summarise, the inclusion of different organism groups in the ecotoxicity testing and a more reliable knowledge of actual concentrations in Swiss compost are the most critical points for a reliable risk assessment. This literature based ecotoxicological risk assessment revealed data gaps in ecotoxicological studies and in reliable estimations of concentrations in compost. When knowledge is lacking risk perception is skewed by emotive attributes of risk. Considering the possible beneficial effects of compost and the potential for a wide usage in the future these gaps in knowledge cannot be ignored. For a refined risk assessment experts and stakeholders should be involved in deciding which gaps have to be filled and in judging the risks in the light of possible benefits.

Table 19: Acceptable (☑) and uncertain (☐) risks of compost used as growth substrate, soil improver or fertilizer under the assumption that the concentrations in Swiss compost do not exceed the concentrations used in this risk assessment (Table 3). E: Too little ecotoxicological information, C: Insufficient data about the concentration in Swiss compost are available for a sound risk assessment.

Chemical Substance		Growth substrate	Soil improver	Fertilizer
Atrazine	FIV, measured	☐ ^{C}	☑	☑
Bisphenol A		☐ $^{E, C}$	☐ $^{E, C}$	☐ $^{E, C}$
Captan l)	FIV	☐ ^{C}	☑	☑
Chlorpyrifos	FIV	☐ ^{C}	☐ ^{C}	☐ ^{C}
	measured	☐ ^{E}	☑	☑
Cyprodinil l)	FIV	☐ $^{E, C}$	☐ $^{E, C}$	☑ ^{E}
PCDD	measured	☑	☑	☑
Folpet l)	FIV	☑ ^{E}	☑ ^{E}	☑ ^{E}
Iprodione	FIV	☐ $^{E, C}$	☐ $^{E, C}$	☑ ^{E}
	measured	☑ ^{E}	☑ ^{E}	☑ ^{E}
Metolachlor l)	FIV	☐ $^{E, C}$	☑ ^{E}	☑ ^{E}
PAH	measured	☑	☑	☑
PCB	measured	☑ ^{E}	☑ ^{E}	☑ ^{E}
DBP	measured	☐ $^{E, C}$	☑ ^{E}	☑ ^{E}
DEHP	measured	☑ ^{E}	☑ ^{E}	☑ ^{E}
PBDE		☐ $^{E, C}$	☐ $^{E, C}$	☐ $^{E, C}$
Procymidone l)	FIV	☐ ^{E}	☐ ^{E}	☐ ^{E}
Thiabendazole	FIV	☐ $^{E, C}$	☐ $^{E, C}$	☐ $^{E, C}$
	measured	☑ ^{E}	☑ ^{E}	☑ ^{E}
Trifluralin	FIV, measured	☑ ^{E}	☑ ^{E}	☑ ^{E}
Vinclozolin	FIV	☐ $^{E, C}$	☐ $^{E, C}$	☑ ^{E}
	measured	☑ ^{E}	☑ ^{E}	☑ ^{E}

l) *No measured concentration data available.*

Table 20: Chemical substances and organism groups for which studies with relevant ecotoxicological endpoints could be found. Further studies were found in literature, but were not suitable for this risk assessment (see Annex I).

	Worms	Collembola	Soil mites	Beetles	Other invertebrates
Atrazine	x	x		x	x
Bisphenol A					
Captan	x			x	
Chlorpyrifos	x	x			x
Cyprodinil	x				
PCDD	x	x		x	
Folpet	x			x	
Iprodione	x				
Metolachlor	x				
PAH	x	x			x
PCB	x	x			
Phthalates	x	x			
PBDEs					
Procymidone					
Thiabendazole	x				x
Trifluralin	x				
Vinclozolin	x				

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