Annex I

Atrazine 3
Bisphenol A 10
Captan 11
Chlorpyrifos 18
Cyprodinil 25
Dioxine (PCDD) 28
Folpet 31
Iprodione 34
Metolachlor 36
PAH 39
PCB 48
Phthalate 52
Polybrominated diphenylethers (PBDE) 56
Procymidone 57
Thiabendazole 58
Trifluralin 60
Vinclozolin 63
Ecotoxicological Literature 65

Atrazine

Usage and environmental behaviour

CAS-No: 1912-24-9
Chemical group: triazine
Type: Herbicide
Chemical data: log Kow 2.5 (25°C); Koc 39-173 l/kg
Selected uses: corn, sorghum, sugarcane, pineapple, Christmas trees

Selected registered applications in Switzerland

Name of product	Content of a.i.[1]	Application rate of the product
Atrazine 90 WG	90%	1 kg/ha
Gesaprim Quick	90%	1.1 kg/ha
Atrazin FL	500 g/l	2 l/ha
Atrazin Hoko	50%	2 kg/ha
Azit	80%	1.25 kg/ha
Atrazin 500 fl	500 g/l	2 l/ha

Atrazine is a selective systemic herbicide. It is absorbed in plants through roots and foliage, where it is translocated upward and accumulated in the growing tips and new leaves. Atrazine blocks the plant's ability to carry on photosynthesis. It has a yearly usage in Switzerland of 35 t/a. It has been detected in compost, but not in fruits or vegetables on the market. It is moderately to highly mobile in soil and does not strongly adsorb, especially where soils have low clay or organic matter content. The half-life (DT50) of atrazine in the field is given between 5 to 119 d. The longer values being from cold or dry conditions. It has been described as being active in the soil for 5-7 months.

Ecotoxicity

Worms

Laboratory studies

Species: *Eisenia fetida*
Duration: 14 d
Test conditions: soil
LC50: 78 mg/kg soil
Ref: (PM)
Validity: rudimentary summary

Species: *Lumbricus terrestris*
Test compound: Gesaprim 500 fl (Atrazine, 480 g/l)
Duration: 14 d
Test conditions: soil (adults, 18/conc)
LC50: 925.9 mg product/kg dry soil (444 mg ai/kg dry soil)
Ref: (Haque et al. 1983)
Validity: study GLP-similar quality
Comment: test development for OECD

Species: *Eisenia fetida*
Test compound: Gesaprim 500 fl (Atrazine, 480 g/l)
Duration: 14 d
Test conditions: soil (adults, 18/conc)
LC50: 272.8 mg product/kg dry soil (131 mg ai/kg dry soil)
Ref: (Haque et al. 1983)

[1] a.i. active ingredient

Validity: study GLP-similar quality
Comment: test development for OECD

Species: *Tubifex tubifex*
Test compound: Atrazine 50%
Duration: 7 d
Test conditions: watery medium with a sand-soil mixture sediment (0-1000 mg/l; 20/conc)
LC50: 140 mg ai/l
Ref: (Högger et al. 1994)
Validity: scientific literature

Species: *Eisenia fetida*
Test compound: Atrazine 50%
Duration: 14 d
Test conditions: artificial soil
LC50: 131 mg ai/kg
Ref: (Högger et al. 1994)
Validity: summary, cited as OECD guideline 207

Species: *Eudrilus eugeniae*
NOEC: 32 mg/kg
NOEC corrected for org. matter in soil (details not given): 160 mg/kg
Ref: (Badejo et al. 1992)
Validity: summary
Comment: used for HC5 (see Collembola)

Further studies were carried out with clean soil, which was incubated with C14-atrazine for 100 d and then thoroughly extracted. Some residues were left in the soil, which were called the 'initially bound residue'. The extracted soil was then mixed with spiked soil (Atrazine >98% pure, not C14 labelled) and earthworms (*Aporrectodea longa*) were exposed to it for 28 d. The results were that a very small amount of bound residues can be bioavailable to earthworms (<0.2%) and that the presence of earthworms retarded bound residue formation of freshly introduced C14-atrazine. Microbial activity made 24% of the non extractable residues extractable (not necessarily due to earthworms). Earthworms can thus enhance the degradation of fresh atrazine.
Ref: (Gevao et al. 2001)
Validity: scientific literature, confusing study, effect of earthworms not very clear.

Field studies

No studies found.

Assessment

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

Collembola

Laboratory studies

Species: *Onychiurus armatus*
Test compound: pure atrazine
Duration: 30 and 60 d
Test conditions: sterile sand substrate (2.5–160 mg/kg, mortality only from 20-160 mg/kg; sexually mature animals, 75/conc)
LD50: 20 mg/kg (30 d)
Ref: (Mola et al. 1987)
Validity: scientific literature, not very good
Comment: Oviposition, birth, development and subsequent reproduction of newborns not affected at 2.5, 5 and 10 mg/kg. Oviposition does not occur at >20 mg/kg. LD50 in ppm is used in the text even though the animals were exposed to sand contaminated with atrazine. Therefore the dose taken up by the collembolas could not have been known.

Species: *Onychiurus apuanicus*
Test compound: pure atrazine
Duration: 30 and 60 d
Test conditions: sterile sand substrate (2.5–160 mg/kg, sexually mature animals, 75/conc)
LD50: 17.2 mg/kg (30 d)
NOEC, NOEL: <2.5 mg/kg
Ref: (Mola et al. 1987)
Validity: scientific literature, not very good
Comment: High mortality even at 2.5 mg/kg; birth, development and subsequent reproduction of newborns not affected at 2.5, 5 and 10 mg/kg. Oviposition does not occur at >20 mg/kg. LD50 in ppm is used in the text even though the animals were exposed to sand contaminated with atrazine. Therefore the dose taken up by the collembolas could not have been known.

Species: *Orchesella cincta*
Duration: 42 d
Test conditions: culture pots with and without food discs (0-640 mg/kg food; young adults, 50 or 100/conc)
LC50: 224 mg/kg food
Ref: (Badejo et al. 1992)
Validity: scientific literature, good
Comment: Mortality and moulting were observed; moulting frequency and rate of increase in mass not affected, no food avoidance.

Species: *Orchesella cincta*
Duration: 40 d
Test conditions: culture pots with 2 food discs (10-80 mg/kg food; young adults (40/conc)
NOEC: 40 mg/kg food (egg production and development)
Ref: (Badejo et al. 1992)
Validity: scientific literature, good
Comment: Growth and reproduction were observed. Atrazine affects egg production at 80 mg/kg, but not growth.

Species: various – see following table
NOEC: see following table
Ref: (Badejo et al. 1992)
Validity: scientific literature, good
Comment: endpoints used for the calculation of HC5. 2.7 mg/kg atrazine was estimated to be the hazardous concentration for 5% of soil invertebrates (HC5) based on the NOEC of atrazine for *O. cincta* and four other members of the soil fauna

Species	NOEC (mg/kg)	NOEC corrected for org. matter in soil (details not given) (mg/kg)
Eudrilus eugeniae (worm)	32	160
Tullbergia granulata	1000	333
Folsomia candida	600	200
Onychiurus armatus	10	50
Orchesella cincta	40	13.3

Further studies were carried out in the laboratory with 580, 1460, 2330 mg ai/kg fresh weight food (Baker's yeast) using *Entomobrya musatica*. 10 juveniles were observed for instar duration length and 100 adults for fecundity for 21 d. Moulting, growth and egg production were observed for 2 months. At 580 mg/kg a slight effect on fecundity was observed. At 1460 mg/kg the fecundity and instar duration period was affected. At 2330 mg/kg marked negative effects on egg production and duration length of instars were observed. NOEC: < 580 mg ai/kg fresh weight food.
Ref: (Al-Assiuty et al. 1996)
Validity: scientific literature, simple, not very good

Field studies

Study in Egypt: 0, 1.6, 4.0, 6.3 kg ai/ha treatments; Collembola (*Entomobrya musatica*) densities were estimated four times during 1 year after treatment (30 d wait). At 1.6 kg/ha intensive vertical migration was observed. Significant reductions in abundance were observed at 4.0 kg/ha (50%) and 6.3 kg/ha (75%). 4.0 kg ai/ha had also adverse effects on the development.
NOEC: <1.6 kg ai/ha
Ref: (Al-Assiuty et al. 1996)
Validity: scientific literature, simple, not very good

3 fields, one of which had not been previously treated with atrazine, were treated with 0, 2, 4, 6 kg/ha. The previously untreated field showed a decrease in number of microarthropods living in superficial soil layer, especially at 6 kg/ha. Losses were for the most part followed by a recovery within one month. NOEC: <2 kg/ha
Ref: (Mola et al. 1987)
Validity: scientific literature

Assessment

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, chronic and reproductive toxic effects were observed in culture pots. The study was not carried out according to guidelines, but seemed controlled and reliable. The LC50 after 42 d was 224 mg/kg food and the NOEC 40 mg/kg food. At concentrations above the NOEC oviposition was affected and long-term effects can therefore be expected. In the 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 scenario II criteria). 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.

Mites

No studies found.

Beetles

Laboratory studies

Laboratory and greenhouse studies with 5 carabid beetles (*Amara* sp*., Agonum* sp*., Pterostichus* sp*., Anisodactylus* sp*., Harpalus* sp.) showed no significant acute or chronic effects on male or female carabid longevity or food consumption during one year after exposure to initial field-rate applications (2.24 kg ai/ha). Initial repellent effects were only observed during the first three days in greenhouse studies. 20 beetles per group (2 w, 2 m x 5 species), first year adults. The exposure was maximised by spraying the soil and food as well as submerging the beetles in the herbicide.
NOEC: > 2.24 kg ai/ha
Ref: (Brust 1990)
Validity: scientific literature, controlled

Field studies

No toxic or repellent effect in the field on beetles at 2.24 kg ai/ha.
Ref: (Brust 1990)
Validity: scientific literature, controlled

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 ai/ha.

Other invertebrates

Laboratory studies

Atrazine individually was not acutely toxic even at high concentrations (10 mg/l) to larvae of the midge *Chironomous tentans* (fourth instar, 96 h, 50 larvae), however low concentrations of atrazine (0.04-0.2 mg/l) increased the toxicity of chloroyrifos, methyl parathion and diazinon. A larger amount of polar metabolites was generated in the presence of atrazine compared to chlorpyrifos alone. The EC50 of chlorpyrifos decreased from 0.44 to 0.11 μg/l in the presence of 0.2 mg/l atrazine, thus atrazine increases the toxicity of chlorpyrifos four fold.
Ref: (Belden et al. 2000)
Validity: scientific literature, controlled study

Field studies

Study in brown soil, 5 and 8 kg ai/ha. Sampling of soil fauna was carried out one (May) and four (Sept.) months after treatment. The results show a pronounced sensitivity of the soil fauna to atrazine, except the nematodes. The decrease of protozoa, enchytraeidae, acari, collembola and adult insect populations was proportional to the concentration of atrazine. The inhibition of soil protozoa was still present four months after the application. Less affected were Oribatidae. Isotomidae showed a greater resistance than other collembola populations. Hypogastruridae and Symphypleona were completely removed.
Ref: (Popovici et al. 1977)
Validity: old field study

Maize fields were treated with 0, 2, 4, 6 kg ai/ha. On the field, which had never been treated with atrazine before, a decrease in microarthropods in the superficial surface soil layer was observed, especially at 6 kg/ha. The losses were followed by recovery within one month. The effects seemed to be nil or only very small at the recommended application rate (2 kg/ha). In two other fields which were previously treated with atrazine no decrease was observed. The difference between these two sites might have been due to specific binding properties of the soil.
NOEC: 2 kg ai/ha
Ref: (Mola et al. 1987)
Validity: scientific literature, no detailed description (mentioned in the introduction to other data)

Assessment

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 ai/ha were observed. Observed losses at 6 kg ai/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 ai/ha.

Soil microorganisms

Effect of atrazine on microorganism is small.
Validity: www database

Soil microcosm columns: 30, 60, 90 d; Atrazine application at 10 mg/kg induced a population increase of the soil indigenous ammonia-oxidizer, but at 100 mg/kg significant increase in ammonium levels suggesting a drop in soil nitrification for at least 90 d. At 1000 mg/kg the ammonia-oxidizer population dropped below detection limit. Ammonia oxidizers were affected in abundance and community structure. NH4+ increased at >100 mg/kg, nitrate was stable.
NOEC: 10 mg/kg.
Ref: (Chang et al. 2001)
Validity: scientific literature, controlled

Loam soil: Applications of 10, 30, 100 mg atrazine/kg air dry soil. Increased populations of actinomycetes, bacteria and fungi were observed at 30 and 100 mg/kg by day 15 and persisted for 2 months. Accumulation factors: from soil – actinomycetes 26x, fungal mycelia 13x.
NOEC: 10 mg/kg
Ref: (Percich et al. 1978)
Validity: scientific literature, ok

30 and 100 mg/kg increased population of antinomycetes, bacteria and fungi in a loam soil; organisms accumulated atrazine only at ambient levels in 3 d without evidence of breakdown.
Ref: (Percich et al. 1978)
Validity: only abstract

Assessment

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.

Birds

Test compound	Adminis-tration	Species	Duration	LC50 mg/kg	LD50 mg/kg	NOEC mg/kg	Ref.
Atrazine	oral	mallard duck	acute		>2000		(Extoxnet) (PM)
	oral	bobwhite quail	acute		940	>5000	(Extoxnet) (PM)
	oral	ring-necked pheasant				>5000	(Extoxnet)
	diet	japanese quail (chicks) (adults)	8 d	>5000 >1000			(PM)

Mammals

Test compound	Administration	Species	Duration	LD50	NOEC	Ref.
Atrazine	oral	mouse	acute	>1332-3992 mg/kg		(PM)
	oral	rat	acute	1869-3090 mg/kg	10 mg/kg diet	
	oral	rat	acute	672-3000 mg/kg		(Extoxnet)

Further studies demonstrated that 40% of rats receiving oral doses of 20 mg/kg/d for 6 months died with signs of respiratory distress and paralysis of the limbs. Morphological and biochemical changes in the brain, heart, liver, lungs, kidney, ovaries and endocrine organs were observed. Rats fed 5-25 mg/kg/d of atrazine for 6 months exhibited growth retardation. Examination of these rats revealed no lesions of the inner organs.
Ref: (Extoxnet)

Literature

Al-Assiuty, A. I. M., and M. A. Khalil. 1996. Effects of the herbicide atrazine on Entomobrya musatica (Collembola) in field and laboratory experiments. *Applied Soil Ecology* 4:139-146.

Badejo, M. A., and N. M. van Straalen. 1992. Effects of atrazine on growth and reproduction of Orchesella cincta (collembola). *Pedobiologia* 26:221-230.

Belden, J. B., and M. J. Lydy. 2000. Impact of atrazine on organophosphate insecticide toxicity. *Environmental Toxicology and Chemistry* 19 (9):2266-2274.

Brust, G. E. 1990. Direct and indirect effects of four herbicides on the activity of carabid beetles (Coleoptera: carabidae). *Pesticide Science* 30:309-320.

Chang, Y. J., A. K. M. A. Hussain, J. R. Stephen, M. D. Mullen, D. C. White, and A. Peacook. 2001. Impact of herbicides on the abundance and structure of indigenous β-subgroup ammonia-oxidizer communities in soil microcosms. *Environmental Toxicology and Chemistry* 20 (11):2462-2468.

Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].

Gevao, B., C. Mordaunt, K. T. Semple, T. G. Peiearce, and K. C. Jones. 2001. Bioavailability of nonextractable (bound) pesticide residues to earthworms. *Environmental Science and Technologie* 35:501-507.

Haque, A., and W. Ebing. 1983. Toxicity determination of pesticides to earthworms in the soil substrate. *Z. PflKrankh. PflSchutz* 90:395-408.

Högger, C. H., and H. U. Ammon. 1994. Testing the toxicity of pesticides to earthworms in laboratory and field tests. *IOBC wprs Bulletin* 17:157-178.

Mola, L., M. A. Sabatini, B. Fratello, and R. Bertolani. 1987. Effects of atrazine on two species of collembola (Onychiuridae) in laboratory tests. *Pedobiologia* 30:145-149.

Percich, J. A., and J. L. Lockwood. 1978. Interaction of atrazine with soil microorganisms: population changes and accumulation. *Can. J. Microbiol.* 24:1145-1152.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Popovici, I., G. Stan, V. Stefan, R. Tomescu, A. Dumea, A. Tarta, and F. Dan. 1977. The influence of atrazine on soil fauna. *Pedobiologia* 17:209-215.

Bisphenol A

Usage and environmental behaviour

Chemical data: low volatility, log Pow 3.4; Koc 314-1524
Used in: production of polycarbonate, epoxy resin, unsaturated polyester-styrene resin and flame retardants; final product used as coating in cans, powder paints, thermal paper etc.

Bisphenol A has been detected in seepage water of compost. Its half-life in water and soil is 4.5 d, in the air <1 d. Bisphenol A is easily degradable, has a middle to high sorption affinity to soil and a low bioconcentration factor. Bisphenol A is known to exhibit endocrine effects in vertebrates and invertebrates (Oehlmann et al. 2000).

Ecotoxicity

Worms

No studies found.

Collembola

No studies found.

Mites

No studies found.

Beetles

No studies found.

Other invertebrates

No studies found.

Soil microorganisms

No studies found.

Literature

Oehlmann, J., U. Schulte-Oehlmann, M. Tillmann, and B. Markert. 2000. Effects of endocrine disruptors on prosobranch snails (Mollusca: Gastropoda) in the laboratory. Part I: Bisphenol A and octylphenol as xeno-estrogens. *Ecotoxicology* 9 (6):383-397.

Captan

Usage and environmental behaviour

CAS-No: 133-06-2
Chemical group: phthalimide
Type: Fungicide
Chemical data: log Kow 2.8 (25°C); Koc 44-364 l/kg
Selected uses: fruit, ornamental, vegetable

Selected registered applications in Switzerland

Name of product	Content of a.i.	Application rate of the product
Captan 80	80%	2.4 – 3.2 l/ha
Captan 83	83%	2.4 - 3.2 l/ha
Captan Burri	50%	4 – 4.8 l/ha
Captan FL	600 g/l	3.2 l/ha

Captan is a non-systemic fungicide and inhibits respiration. Captan has a yearly usage in Switzerland of 45 t. It has not been measured in compost, but in fruits or vegetables on the market. The residues on plant leaf surfaces decreased with time and were after 2 d 800 mg/kg, after 13 d 450 mg/kg, after 27 d 150 mg/kg and below the detection limit 40 d after application. It has a short half-life (DT50) of 1-10 d (pH 7.2, 25°C) in soil. It is not mobile in soil.

Ecotoxicity

Worms

Laboratory studies

Species: *Eisenia fetida andrei*
Duration: 48 h
Test conditions: contact filter paper test (1, 0.1, 0.01, 0.001, 0.0001 mg/cm^2; adults, 10/conc)
LC50: 290 µg ai/cm^2
Ref: (Heimbach 1984)
Validity: EEC test guideline

Species: *Eisenia fetida andrei*
Duration: 14 d / 28 d
Test conditions: artificial soil test (0.1, 1, 10, 100, 1000 mg/kg dry weight; adults, 18-40/conc)
LC50: 625 mg ai/kg dw (612 mg ai/kg dw)
Ref: (Heimbach 1984), (Heimbach 1985)
Validity: BBA proposal, partly according to EEC proposal (14 d)

Species: *Eisenia fetida andrei*
Duration: 14 d
Test conditions: artisol test (0.1, 1, 10, 100, 1000 mg/kg dry weight silica, silica mixed with glass balls and water; adults, 30-40/conc)
LC50: 691 mg ai/kg dw
Ref: (Heimbach 1984)
Validity: according to EEC proposal

Species: *Lumbricus terrestris*
Test compound: Orthocid 83 (Captan 83%)
Duration: 14 d
Test conditions: soil (adults, 18/conc)
LC50: 237 mg ai/kg dw
Ref: (Haque et al. 1983)
Validity: test development for OECD

Species: *Tubifex tubifex*
Test compound: Captan 83%
Duration: 7 d
Test conditions: watery medium with a sand-soil mixture sediment (0-1000 mg/l; 20/conc)
LC50: 4.4 mg ai/l
Ref: (Högger et al. 1994)
Validity: scientific publication

Species: *Eisenia fetida*
Test compound: Captan 83%
Duration: 14 d
Test conditions: artificial soil
LC50: 612 mg ai/kg
Ref: (Högger et al. 1994)
Validity: summary, cited as OECD 207
Comment: not clear if the value originates from this study or is cited.

Species: *Eisenia fetida*
Active ingredient: technical 60.2% Captan
Duration: 3 d
Test conditions: filter paper (0.602, 6.02, 120.4, 240.8, 361.2, 481.6, 602, 620 mg ai/kg; 10/conc)
LC50 (48 h): 73.2-79.54 mg ai/kg
LC50 (72 h): 45.93-53.36 mg ai/kg
Ref: (Anton et al. 1990)
Validity: OCDE, ECC guideline - not comprehensible

Species: *Eisenia fetida*
Test compound: technical 60.2% Captan
Duration: 72.5 h (30 min inmersion)
Test conditions: inmersion test (0.602, 60.2, 602, 6020, 6622, 7724, 7286, 8426 mg ai/kg; 10/conc)
LC50 (48 h): 7296.24 mg ai/kg (12120.89 mg technical captan /kg)
LC50 (72 h): 4102.43 mg ai/kg (4102.43 mg technical captan /kg)
Ref: (Anton et al. 1990)
Validity: OCDE, ECC guideline - not comprehensible

Species: *Eisenia fetida*
Test compound: technical 60.2% Captan
Duration: 14 d
Test conditions: artificial soil (602, 1204, 1806, 2408, 3010 mg ai/kg; 15/conc)
LC50: >3010 mg ai/kg
Ref: (Anton et al. 1990)
Validity: OCDE, ECC guideline - not comprehensible
Comment: no production of cocoons, low toxicity due to fast degradation and high adsorption

Species: *Eisenia fetida*
LC50: >519 mg/kg soil
Ref: (Agritox)
Validity: www database

In further studies captan caused a significant reduction ($p<0.01$) in the total immune activity in earthworms (*Eisenia veneta*) at 0.95 mg/ml.
Ref: (Bunn et al. 1996)
Validity: controlled, method development.

The growth rate of *Aporrectodea caliginosa* was measured over 100 d in soil culture chambers. Captan was applied at intervals of 14 d (2'800, 5'600, 11'200 g a.i./ha or 280, 560, 1'120 g ai/ha) and each treatment was replicated six times. Captan depressed the growth when applied alone and reduced the effect of azinphos-methyl and glyphosate when applied in combination. In the presence of captan the number of mature worms was reduced, the time to maturity prolonged and the mortality slightly increased (0-2 dead out of 6).
Ref: (Springett et al. 1992)

Validity: the concentration used is not clear as it differs by a factor of 10 between the graphs and text.

Field studies

Captan was observed to be toxic to earthworms when applied at 9 kg/ha. No further information was given.
Ref: (Anton et al. 1990)

Assessment

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 *E. fetida* was 612 mg/kg dry soil. *Lumbricus terrestris* seemed to be more sensitive to captan, with an LC50 of 237 mg/kg dry soil. In an experiment with *Aporrectodea caliginosa* 2.8 kg/ha (equivalent to 3.7 mg/kg according to 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.

Collembola

No studies found.

Mites

No studies found.

Beetles

Laboratory studies

Species: *Orius insidiosus*,
Test conditions: ventilated glass cages
Ref: internal database
Validity: GLP, guideline
Comment: No mortality observed, classified as harmless at standard application rates

Species: *Orius insidiosus*
Test conditions: oviposition jars
Ref: internal database
Validity: GLP, guideline
Comment: No effect on reproduction and egg-hatch success observed, classified as harmless at standard application rates

Species: *Pterostichus melanarius*
Test conditions: moist soil
Ref: internal database
Validity: GLP, guideline
Comment: No mortality or effects on feeding observed, classified as harmless at standard application rates

Species: *Trybliographa rapae*
Test conditions: glass plate
Ref: internal database
Validity: GLP, guideline
Comment: No mortality or effects on parasitic capacity observed, classified as harmless at standard application rates

Field studies

No studies found.

Assessment

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*, P*terostichus melanarius* and *Trybliographa rapae* at standard application rates.

Other invertebrates

Laboratory studies

Species: *Chrysoperla carnea*
Test conditions: glass plates
E = 23
Ref: internal database
Validity: GLP, guideline
Comment: No mortality observed, classified as harmless at standard application rates

Species: *Typhlodromus pyri*
Test conditions: ventilated glass cage
Ref: internal database
Validity: GLP, guideline
Comment: No mortality observed, classified as harmless at standard application rates

Species: *Typhlodromus pyri*
Test conditions: ventilated glass cage, which were treated one week prior (surviving individuals from previous test)
E = 0
Ref: internal database
Validity: GLP, guideline
Comment: No effect on reproduction observed, classified as harmless at standard application rates

Species: *Aphidius rhopalosiphi*
Test conditions: extended laboratory study
E = 0
Ref: internal database
Validity: GLP, guideline
Comment: No mortality or effects on reproduction observed, classified as harmless at standard application rates

Species: various – see following table
Active ingredient: Captan WP 83%
Test conditions: 500-1000 g/ha
E = 0-19 – see following table
Ref: (Agritox)
Validity: www database

Species	Dose g/ha	Mortality % effect	Reproduction % effect	E
Aphidius rhopalosiphi	500 1000	2.4 2.6	17 6	19 8.4
Chrysoperla carnea	570	-5.1	-5.1	10.4
Paadosa sp.	750	0	0	0

Field studies

No studies found.

Assessment

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

Soil microorganisms

The treatment of forest soil with 25 mg/kg soil reduced significantly the number of active bacteria, fungi and nematodes.
Ref: (Colinas et al. 1994)
Validity: controlled

Treatment with 1 and 50 mg ai/kg soil. The effects on transformation of urea nitrogen were observed in coarse and fine soil. The soil was incubated aerobically with urea for 1, 3, 7 d or 7, 14, 21 d. Results: 1 mg/kg retarded nitrification (by 40% over 14 d, by 6% after 21 d) in coarse soil; 50 mg/kg retarded nitrification over 21 d in coarse soil and to a lesser extend in fine soil (~15% day 21); the extensive retardation of urea hydrolysis may promote leaching of urea during irrigation and the extensive retardation of nitrification of urea nitrogen will disturb the nitrogen status of the soil which could adversely affect plant growth.
Ref: (Martens et al. 1997)
Validity: controlled

Captan decreases nitrification when applied at rates of 250 mg/kg soil.
Ref: (Martens et al. 1997)

Small scale microcosm soil incubation: effect on microbial activity (substrate induced respiration, dehydrogenase activity) and nitrogen dynamics (NH4-N, NO3-N) were observed at 125 mg ai/kg, incubated at 30°C for 56 d. Results: peak soil respiration was suppressed by 30-50% during the first 14 d. Soil dehydrogenase activity increased during the first 7 d, then decreased by 40-58%. Captan treated soils had higher NH4-N concentrations than the control and N mineralization and nitrification rates were significantly higher. None of the effects were large or long-lived.
Ref: (Chen et al. 2001b)
Validity: controlled, method development

Terrestrial microcosms with agricultural soil, organic amendments and wheat seedlings. Applied amount: 125 mg ai/kg soil, 56 d, 4 replicates. Rates of substrate induced respiration, soil enzyme activities (except urease activity), microbial biomass N and dissolved organic N concentrations were all decreased significantly. Rates of wheat straw decomposition were inhibited. Soil urease activity, NH4+-N and NO3-N concentrations, and initial net N mineralizaltion and nitrification rates were increased. Germination success, plant biomass and total nitrogen uptake was increased. Overall microbial activity was decreased significantly, but there was not much change in microbial biomass (shift from fungal to bacterial community).
Ref: (Chen et al. 2001a)
Validity: controlled, method development

Microplots on orchard soil, 2 samples after 5 and 28 d, 76.05 g and 39.55 g ai/microplot (39x39 cm): 5 days after treatment soil fauna was significantly reduced, after 28 d reduction was no longer observed.
Ref: (Rapoport et al. 1968)
Validity: old scientific study

Microcosm system: A) field populations of bacteria, fungi, protozoa (no nematodes, arthropods, plants) were inoculated into sterilized natural soil (25 mg/kg soil – 50% ai). Active hyphal lengths were lower than in controls, but total hyphal lengths, bacterial plate counts and protozoan estimates were not affected by captan; total bacterial counts were only lower on the first day, fungal plate count increased on day 7 and was back to control level on day 14 (that was maybe just a change in fungal dominance), NO3-N and NO2-N was lower on the last sample day. B) Seedlings planted in sterilized soil for 3 weeks, then plus captan (25 mg/kg soil) for 6 weeks. No significant effects.
Ref: (Ingham et al. 1984)
Validity: scientific literature

At a dosage of 1.52 and 15.2 kg ai/ha there was no effect on N and C-mineralisation for 28 d.
Ref: (Agritox)
Validity: www database

Assessment

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.

Birds

Test compound	Administration	Species	Duration	LD50 mg/kg	Ref.
Captan	oral	mallard ducks, pheasants	acute	>5000	(PM)
	oral	bobwhite quail	acute	2000-4000	(PM)

High doses administered for 90 d to chickens caused an 80% reduction in the number of eggs produced but had no effect on the fertility or hatchability of the eggs produced. At lower, but still relatively high doses quail, pheasants and mallards experienced no mortality when fed captan in their food for 74 d.
Ref: (Extoxnet)

Mammals

Test compound	Administration	Species	Duration	LD50 mg/kg	NOEC mg/kg (2 y)	Ref.
Captan	oral	rat	acute	9000 8400 –15000	2000	(PM),(Bunn et al. 1996), (Extoxnet)

Mice fed 50 mg/kg over three generations reproduced normally.
Ref: (Extoxnet)

Literature

Agritox. *http://www.inra.fr/agritox/fiches* INRA, [cited 2003].

Anton, F., E. Laborda, and P. Laborda. 1990. Acute toxicity of the fungicide captan to the earthworm Eisenia foetida (Savigny). *Bull. Environ. Contam. Toxicol.* 45:82-87.

Bunn, K. E., H. M. Thompson, and K. A. Tarrant. 1996. Effects of agrochemicals on the immune systems of earthworms. *Bull. Environ. Contam. Toxicol.* 57:632-639.

Chen, S.-K., C. A. Edwards, and S. Subler. 2001a. A microcosm approach for evaluating the effects of the fungicides benomyl and captan on soil ecological processes and plant growth. *Applied Soil Ecology* 18:69-82.

———. 2001b. Effects of the fungicides benomyl, captan and chlorothalonil on soil microbial activity and nitrogen dynamics in laboratory incubations. *Soil Biol. Biochem.* 33:1971-1980.

Colinas, C., E. Ingham, and R. Molina. 1994. Population responses of target and non-target forest soil organisms to selected biocides. *Soil Biol. Biochem.* 26 (1):41-47.

Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].

Haque, A., and W. Ebing. 1983. Toxicity determination of pesticides to earthworms in the soil substrate. *Z. PflKrankh. PflSchutz* 90:395-408.

Heimbach, F. 1984. Correlations between three methods for determining the toxicity of chemicals to earthworms. *Pesticide Science* 15:605-611.

———. 1985. Comparison of laboratory methods, using Eisenia foetida and Lumbricus terrestris, for the assessment of the hazard of chemicals to earthworms. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 92 (2):186-193.

Högger, C. H., and H. U. Ammon. 1994. Testing the toxicity of pesticides to earthworms in laboratory and field tests. *IOBC wprs Bulletin* 17:157-178.

Ingham, E. R., and D. C. Coleman. 1984. Effects of streptomycin, cycloheximide, fungizone, captan, carbofuran, cygon, and PCNB on soil microorganisms. *Microb. Ecol.* 10:345-358.

Martens, D. A., and J. M. Bremmer. 1997. Inhibitory effects of fungicides on hydrolysis of urea and nitrification of urea nitrogen in soil. *Pesticide Science* 49:344-352.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Rapoport, E. H., and L. Sanchez. 1968. Effect of organic fungicides on the soil microfauna. *Pedobiologia* 7:317-322.

Springett, J. A., and R. A. J. Gray. 1992. Effect of repeated low doses of biocides on the earthworm Aporrectodea caliginosa in laboratory culture. *Soil Biol. Biochem.* 24 (12):1739-1744.

Chlorpyrifos

Usage and environmental behaviour

CAS-No: 2921-88-2
Chemical group: organophosphates
Type: Insecticide
Chemical data: log Kow 4.7; Koc 1250-12600 l/kg
Selected uses: grain, cotton, field, fruit, nut, vegetables, lawns, ornamentals

Selected registered applications in Switzerland

Name of product	Content of a.i.	Application rate of the product
Blocade	1.5%	50 kg/ha
Rimi Werrenkörner	1%	30 kg/ha
Arbezol	207 g/l	3 l/m^3
Xerondo	170 g/l	3 l/m^3
Pyrinex	250 g/l	3 l/ha

Chlorpyrifos is a broad-spectrum, non-systemtic contact insecticide. It has been detected in compost, fruits and vegetables on the market. It is immobile in soil as it adsorbs strongly. The metabolite TCP (trichloropyridin) adsorbs weakly and is moderately mobile in soil. The half-life in aerobic soil is 11-141 d at pH 5.4-7.4. Under anaerobic conditions the half-life is 15-58 d. In another source the half-life for chlorpyrifos in the field is 33-56 d if it is incorporated in the soil and 7-15 d if it is applied on the soil surface.

Ecotoxicity

Worms

Laboratory studies

Species: *Eisenia fetida*
Duration: 14 d
Test conditions: soil
LC50: 210 mg/kg soil
Ref: (PM)
Validity: rudimentary summary

Species: *Eisenia andrei*
Duration: 21 d
Test conditions: natural soil (125, 250, 500, 1000, 2000 mg/kg; 40/conc)
NOEC: 125 mg/kg (mortality)
2000 mg/kg (immune activity)
Ref: (Eason et al. 1999)
Validity: ok, biomarker development
Comment: highly toxic, at 125 mg/kg body weight was reduced

Species: *Tubifex tubifex*
Test compound: Reldan (chlorpyrifos 42%)
Duration: 7 d
Test conditions: watery medium with a sand-soil mixture (0-1000 mg/kg; 20/conc)
LC50: 5.6 mg ai/kg
Ref: (Högger et al. 1994)
Validity: scientific literature

Species: *Pheretima*
Duration: 7 d
Test conditions: artificial soil test (50/conc)

LC50: see table
Ref: (Mostert et al. 2002)
Validity: OECD guideline

Species	Duration	LC50 (mg/kg)
Pheretima sp.	24 h	390
	48 h	330
	7d	180

Species: various – see following table
Test compound: 90% pure chlorpyrifos
Duration: 14 d
Test conditions: soil (40/conc)
LC50: see table
NOEC: see table
Ref: (Ma et al. 1993)
Validity: OECD giudeline, standardised test with different species
Comment: *Lumbricus rubellus* more sensitive than *Eisenia veneta*

Administration	Species	LC50 mg/kg	NOEC (mortality, reproduction)
Artificial soil	*Aporrecta caliginosa*	755	486
	Aporrectodea longa	778	486
	Eisenia fetida	1077	486
	Eisenia veneta	1174	875
	Lumbricus rubellus	129-104	46-83
	Lumbricus terrestris	458	270
Humic sandy soil	*Lumbricus rubellus*	262	4.6
	Eisenia veneta		49

Further studies were carried out with artificial soil in buckets. 50 animals from the *Pheretima* group were exposed for 21 d to 2.4 kg/ha. Significant effects on earthworm mortality were only observed 7 d after the application (not 24 h, 14 d, 21 d, even though after 14 d and 21 d mortality more than double from control). A significant (51.8%) decrease in biomass was observed after 21 d. The individual earthworm mass did not decrease much.
Ref: (Mostert et al. 2000)
Validity: controlled, OECD guideline

In a biomarker assay with adult and juvenile *Aporrectodea caliginosa* in natural soil (heated) 80 juveniles/conc and 40 adults/conc were exposed to field (6.15 g ai/m^3 = 4 mg/kg) and higher (28 mg/kg) sublethal concentrations for 4 weeks. Juveniles were analysed for cholinesterase activity, glutathione S-transferase activity (GST: detoxification of xenobiotics), and growth; adults for lysosomal neutral red retention time (NRR: measure of membrane stability) and growth. Cholinesterase and NRR were more sensitive indicators than growth. Maturation was less sensitive than cocoon production. Growth and cocoon production in juveniles was more sensitive than in adults. In juveniles GST was not affected. 28 mg/kg significantly affected juvenile growth, also at 4 mg/kg already a 40% decrease in growth. In adults NRR was significantly reduced and growth was affected at both concentrations (at 28 mg/kg significantly).
Ref: (Booth et al. 2001)
Validity: OECD guideline 207

Assessment

A number of toxicity studies of chlorpyrifos on worms exists. 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*, investigated with more sophisticated biochemical methods, was even more sensitive with a NOEC < 4 mg/kg.

Collembola

Laboratory studies

Species: *Folsomia candida*
Duration: 28 d
Test conditions: soil
NOEC: 0.05 mg/kg
Ref: personal communication (Frank Riepert, Biologische Bundesanstalt Berlin)
Comment: reproduction

Species: *Folsomia candida*
Duration: 28 d
Test conditions: artificial soil (0.05, 0.1, 0.2, 0.33, 0.66, 0.96 mg/kg)
LC50: 0.13 mg/kg (mortality)
Ref: (Stämpfli 2001)
Validity: guideline ISO
Comment: reproduction more sensitive than mortality, reproduction and mortality were already affected at 0.05 mg/kg

Species: *Folsomia candida* (4 clones)
Duration: 35 d
Test conditions: artificial soil (0.03, 0.07, 0.15, 0.32, 0.7 mg ai/kg dry soil; 10 d old juveniles, 4x50/conc)
LC50: 0.2 mg/kg (see table for the sensitivity of different clones)
Ref: (Crommentuijn et al. 1995)
Validity: OECD
Comment: differences between clones small but significant; sexually mature after 15-20 d, growth and numbers of juveniles not affected by sublethal concentrations.

Clone	LC50 (mg/kg)
1	0.28
2	0.24
3	0.24
4	0.2

Sandy clay loam and sandy soil were sprayed with 480 g/ha. Collembola were exposed for 24 h periods on the sprayed soils in a constant laboratory environment 1, 2, 3, 8 and 15 d after treatment. Residues of chlorpyrifos were toxic to all four species of collembola (*Isotoma viridis, Isotomurus palustris, Folsomia candida, Sminthurus viridis*). 60-80% died during the first day after treatment. Exposure 8 days after the treatment lead to no increased mortality.
Ref: (Wiles et al. 1996)
Validity: controlled
Comment: application rate not clear

Field studies

In a field study the toxic effects of 200 l/ha of 480 g/l solution was tested on soil invertebrates. 14 species of collembola were decreased in numbers for eight weeks after treatment. Chlorpyrifos also affected *Entomobrya multifasciata*, *Thysanoptera*, *Aitodiplosis mosellana* larvae, and all diptera larvae. Recovery was not expected within 0.8-1.1 years given the toxicity and persistence of the chemical. The negative effects of chlorpyrifos on canopy-inhabiting arthropods persisted even through heavy rainfall had occurred within 32 h of the insecticide application.
Ref: (Frampton 1999)
Comment: The dilution of the product in water is not clear.

Assessment

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 between 0.2-0.28 mg/kg dry soil depending on the clones tested. However, in two other studies reproduction of *Folsomia candida* was more sensitive than mortality with a NOEC (reproduction) of 0.05 mg/kg and a LC50 of 0.13 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 our scenario II criteria) 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.

Mites

No studies found.

Beetles

Laboratory studies

Species: *Popillia japonica* (3-instar),
Duration: 14 d
Test conditions: thorax, bioassay in cups (natural soil + grass seed) (2x 0.01, 0.1, 1, 10, 100 μg; 40-60 org/conc)
LC50: 0.76 μg/grub
Ref: (Cowles et al. 1994)
Validity: ok

Species: *Hippodamia convergens*
Duration: 3 d
Test conditions: topical (10, 50, 100, 200, 300, 800 mg/l; 40/conc)
LD50: 6 h 16.5
24 h 2.4
48 h 1.2
72 h 1.0 mg/kg (per insect)
Ref:(Kaakeh et al. 1996)
Validity: ok, controlled
Comment: concentrations (mg/l) were corrected for insect body weights to describe the dose (mg/kg) each beetle received on treatment.

While one further study did not detect any negative effects to non-target insects when chlorpyrifos was applied to rice fields at 0.01 to 0.02 kg/ha, another study reported that practically all nontarget insects died after a similar application.
Ref: (Extoxnet)
Validity: rudimentary summary

Field studies

10 beetles *Pterostichus melanarius* per microplot were exposed for 10 d to 0.72 kg ai/ha in a fine tilth seed bed. The beetles were introduced 48 h before and immediately or 24 h after spraying. Mortality was always greater than in the control, but there was a high total recovery at the end of the experiment. In a further test the effect of aggregate size on mortality was studied. In the soil with large aggregate size the mortality was lower. The spray of chlorpyrifos was more toxic than the granules in the fine tilth bed.
Ref: (Bale et al. 1992)
Comment: 2 additional studies which showed no increased mortality and one detailed study with long-term monitoring (0.72 kg/ha) showed significant reduction in the total adult and larval populations of carabids (with some species variation) persisting for 18 months.

Assessment

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 was not defined.

Other invertebrates

Laboratory studies

Species: *Chironomus tentans*, fourth instar
Duration: 96 h
Test conditions: static, 30 midges
LC50: 0.39 μg/l
Ref: (Belden et al. 2000)
Validity: controlled

Species: *Musca domestica*, 3 d old
Duration: 24 h
Test conditions: topical
LD50: 0.04 μg/fly
Ref: (Al-Badry et al. 1980)
Validity: scientific literature

Species: *Porcellio scaber*
Duration: 5 d
Test conditions: soil and leaves (0.01 and 0.1 mg/kg; 20/conc)
LD50: 2 mg/kg
Ref: (Nair et al. 2002)
Validity: reasonably controlled, but no guideline (from Libya)
Comment: highly toxic, body weight not affected.

Species	Administration	Duration (h)	LC50 mg/kg	Ref.
Porcellio scaber	Soil and leaves	24	27.54	(Nair et al. 2002)
		48	15.84	
		72	7.41	
		96	5.25	
		120	2	

Field studies

Six study plots under mature pine and oak trees were treated with 52.2 kg ai/ha and 261 kg ai/ha. The results showed progressive negative effects on collembolans, severe effects on actinedid mites, and moderate effects to all other elements of the arthropod community. The effect (decreasing abundance) increased with time, with the most severe effect at 138 d post treatment. At both applications the collembolan fauna was obliterated. Oribatid mites were little affected at the high rate.
Ref: (Hoy et al. 1981)
Validity: ok

On 6 replicate fields with faba bean as crop treated with 0.75 kg ai/ha (0.8 ml ai/plot; 4x4m), insect traps were positioned over 4 weeks (5 d before spraying). Pest beetles (*Gonocephalum adelaidae*), lycosid spider and wolf spider *Labidura truncata* were not affected. The abundance of carabid beetles decreased 4 d after treatment.
Ref: (Curtis et al. 1995)
Validity: ok

Assessment

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 ai/ha), which caused negative effects on collembolas and actinedid mites exceeded by far the application rate in Switzerland (0.75 kg/ha).

Soil microorganisms

A study was carried out with loamy soil in five petri dishes for 1, 3, and 7 d. Chlorpyrifos at 10-300 mg/kg significantly decreased numbers of aerobic dinitrogen fixing bacteria, total number of bacteria and dinitrogen fixation. Fungal populations and denitrifying bacteria were not affected.
Ref: (Martinez-Toledo et al. 1992)

Validity: ok

In a comparison of the formulated and technical insecticide in sandy loam soil treated with 10 mg/kg populations of bacteria initially decreased, but recovered rapidly to levels similar to those of controls after three weeks. The populations of fungi increased after 1 week and significantly after 3 weeks. Nitrification, sulfur oxidation and microbial activity were not affected.
Ref:(Tu 1991)
Validity: ok

Assessment

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.

Birds

Test compound	Adminis-tration	Species	Duration	LC50 mg/kg	LD50 mg/kg	NOEC mg/kg	Ref.
Chlorpyrifos	oral	pheasant			8.41		(Extoxnet)
		mallard ducks	Acute		112 490	25	(Extoxnet) (PM)
		house sparrows			21		(Extoxnet)
	diet	bobwhite quail	8 d	423	108	125	(Extoxnet) (PM)

Mammals

Test compound	Adminis-tration	Species	Duration	LD50 mg/kg	NOEC	Ref.
Chlorpyrifos	oral	rat	acute	82-270 135-163	1 mg/kg bw daily (2 y)	(Extoxnet) (PM)
	oral	mice	acute	60	0.7 mg/kg bw daily (18 mo)	(Extoxnet) (PM)

Literature

Al-Badry, M. S., and C. O. Knowles. 1980. Phthalate-organophosphate interactions: toxicity, penetration, and metabolism studies with house flies. *Archives of Environmental Contamination and Toxicology* 9:147-161.

Bale, J. S., M. Ekebuisi, and C. Wright. 1992. Effect of seed bed preparation, soil structure and release time on the toxicity of a range of grassland pesticides to the carabid beetle Pterostichus melanarius (Ill.) (Col., Carabidae) using a microplot technique. *J. Appl. Ent.* 113:175-182.

Belden, J. B., and M. J. Lydy. 2000. Impact of atrazine on organophosphate insecticide toxicity. *Environmental Toxicology and Chemistry* 19 (9):2266-2274.

Booth, L. H., and K. O'Halloran. 2001. A comparison of biomarker responses in the earthworm aporrectodea caliginosa to the organophosphorus insecticides diazinon and chlorpyrifos. *Environmental Toxicology and Chemistry* 20 (11):2494-2502.

Cowles, R. S., and M. G. Villani. 1994. Soil interaction with chemical insecticides and nematodes used for control of Japanese beetle (Coleoptera: Scarabaeidae) larvae. *Entomological Society of America* 87 (4):1014-1021.

Crommentuijn, T., J. A. Stäb, A. Doornekamp, O. Estoppey, and C. A. M. van Gestel. 1995. Comparative ecotoxicity of cadmium, chlorpyrifos and triphenyltin hydroxide for four clones of the parthenogenetic collembola Folsomia candida in an artificial soil. *Functional Ecology* 9:734-742.

Curtis, J. E., and P. A. Horne. 1995. Effect of chlorpyrifos and cypermethrin applications on non-target invertebrates in a conservation-tillage crop. *J. Aust. ent. Soc.* 34:229-231.

Eason, C. T., C. Svendsen, K. O'Halloran, and J. M. Weeks. 1999. An assessment of the lysosomal neutral red retention test and immune function assay in earthworms (Eisenia andrei) following exposure to chlorpyrifos, benzo-a-pyrene (BaP), and contaminated soil. *Pedobiologia* 43:641-645.

Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].

Frampton, G. K. 1999. Spatial variation in non-target effects of the insecticides chlorpyrifos, cypermethrin and pirimicarb on Collembola in winter wheat. *Pesticide Science* 55:875-886.

Högger, C. H., and H. U. Ammon. 1994. Testing the toxicity of pesticides to earthworms in laboratory and field tests. *IOBC wprs Bulletin* 17:157-178.

Hoy, J. B., and P. J. Shea. 1981. Effects of lindane, chlorpyrifos and carbaryl on a california pine forest soil arthropod community. *Environ. Entomol.* 10:732-740.

Kaakeh, N., W. Kaakeh, and G. W. Bennett. 1996. Topical toxicity of imidacloprid, fipronil, and seven conventional insecticides to the adult convergent lady beetle (Coleoptera: Coccinellidae). *J. Entomol. Sci.* 31 (3):315-323.

Ma, W.-C., and J. Bodt. 1993. Differences in toxicity of the insecticide chlorpyrifos to six species of earthworms (Oligochaeta, Lumbricidae) in standarised soil tests. *Bull. Environ. Contam. Toxicol.* 50:864-870.

Martinez-Toledo, M. V., V. Salmeron, and J. Gonzalez-Lopez. 1992. Effect of the insecticides methylpyrimifos and chlorpyrifos on soil microflora in an agricultural loam. *Plant and Soil* 147:25-30.

Mostert, M., A. S. Schoeman, and M. van der Merwe. 2000. The toxicity of five insecticides to earthworms of the Pheretima group, using an artificial soil test. *Pest Management Science* 56:1093-1097.

Mostert, M. A., A. S. Schoeman, and M. van der Merwe. 2002. The relative toxicities of insecticides to earthworms of the Pheretima group (Oligochaeta). *Pest Management Science* 58:446-450.

Nair, G. A., A. I. Mohamed, and M. H. Haeba. 2002. Laboratory studies on the LD50 of the woodlouse, Porcellio scaber Latreille (Isopoda, Oniscidea) exposed to chlorpyrifos (Dursban). *Afr. J. Ecol.* 40:393-395.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Stämpfli, C. 2001. Etude des relations entre l'exposition de folsomia candida à un micropollutant organique et les effets observés à différents niveaux d'organisation biologique: utilité des biomarqueurs comme outil prévisionnel., École Polytechnique Fédérale de Lausanne, Lausanne.

Tu, C. M. 1991. Effect of some technical and formulated insecticides on microbial activities in soil. *J. Environ. Sci. Health* B26 (5+6):557-573.

Wiles, J. A., and G. K. Frampton. 1996. A field bioassay approach to assess the toxicity of insecticide residues on soil to collembola. *Pesticide Science* 47:273-285.

Cyprodinil

Usage and environmental behaviour

CAS-No: 121552-61-2
Chemical group: pyrimidine, aniliopyrimidin
Type: Fungicide
Chemical data: log Kow 4 (pH 5, 7, 9)
Selected uses: fruit

Selected registered applications in Switzerland

Name of product	Content of a.i.	Application rate of product	Max. application / year
Chorus	50%	0.8 kg/ha	4

Cyprodinil is a systemic fungicide, which is taken up into plants after foliar application and transported throughout the tissue and acropetally in the xylem. It inhibits penetration and mycelial growth both inside and on the leaf surface. Cyprodinil has not been detected in compost, but in fruits or vegetables on the market. It is immobile in soil and has a half-life of 20-60 d.

Ecotoxicity

Worms

Laboratory studies

Species: *Eisenia fetida*
Duration: 14 d
Test conditions: soil
LC50: 192 mg/kg soil
Ref: (PM)
Validity: OECD guideline

Field studies

No studies found.

Assessment

The only LC50 value given for *Eisenia fetida* is 192 mg/kg determined according to the OECD guideline 207.

Collembola

No studies found.

Mites

Laboratory studies

No studies found.

Field studies

Croatian orchards were treated three times over 2 years up to 96 h after the onset of infection. The concentration is not given. No effects on the mite population (*Pananychus ulmi, Aculus schlechtendali, Tetranychus urticae*) were observed.
Ref: (Ciglar et al. 2000)

Assessment

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

Beetles

No studies found.

Other invertebrates

Laboratory studies

In a rudimentary summary cyprodinil was described as practically non-toxic to *Poecilus cupreus*.
Ref: (Agritox)
Validity: www database

In another rudimentary summary cyprodinil was described as harmless to *Poecilus cupreus*, *Episyrphus* and mites.
Ref: (PM)
Validity: rudimentary summary

In an acute toxicity test *Typhlodromus pyri* were placed on round bean leaf disks (sprayed with cyprodinil + captan) and fed with *Tetranychus urticae*. Cyprodinil in the combination with captan was described as harmless at standard application rates.
Ref: internal database
Validity: good, no guideline

Field studies

Plots of grapes were sprayed four times at standard application rates. The *Typhlodromus pyri* population count was very similar to untreated control and the product was thus assessed as harmless at standard application rates.
Ref: internal database
Validity: good, no guideline

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.

Soil microorganisms

No studies found.

Birds

Test compound	Adminis-tration	Species	Duration	LC50 mg/kg	LD50 mg/kg	Ref.
Cyprodinil		mallard duck bobwhite quail	8 d	>5200	>2000	(PM)

Mammals

Test compound	Adminis-tration	Species	Duration	LD50 mg/kg	NOEC mg/kg bw	Ref.
Cyprodinil	oral	mouse	acute		196 (1.5 y)	(PM)
		rat		>2000	3 (2 y)	

Literature

Agritox. *http://www.inra.fr/agritox/fiches* INRA, [cited 2003].

Ciglar, I., and B. Baric. 2000. Side effect of some fungicides on the mite population in an appli orchard in Croatia. *J. Pest Science* 73:110-112.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Dioxine (PCDD)

Usage and environmental behaviour

Dioxins are poorly water soluble. They are immobile in soil where they strongly adsorb. They have a half-life (DT50) of 1-10 a and are not taken up by plants (only adsorbed). Dioxins are formed during combustion processes if chloride is present and are possibly also produced biogenic.

Ecotoxicity

Worms

Laboratory studies

Species: earthworms (species not defined)
Duration: 14 d
Test conditions: soil (0.05-10 mg OCDD/kg)
LC50: > 10 mg/kg soil
Ref: (van Straalen et al. 1995)
Validity: rudimentary summary; no effects on reproduction up to 5 mg/kg, 10 mg/kg was not tested for effects on reproduction.

Species: *Aporrectodea caliginosa*
Duration: 85 d
Test conditions: sandy loam soil (0.05, 0.5, 1.5, 5.0, 10 mg TCDD/kg)
NOEC, NOEL: 5 mg/kg soil
Ref: (van Straalen et al. 1995)
Validity: rudimentary summary
Comment: at 10 mg/kg all worms had died by day 30. No mortalities were observed at 5 mg/kg. Other effects were not observed.

Aporrectodea caliginosa and *Lumbricus rubellus* were exposed in groups of three individuals to TCDD-treated filter paper (0.02 pg/cm^2 to 3.13 μg/cm^2). Different worms were exposed for 24 h up to 8 d; after the exposure, worms were kept on clean, moist filter paper and later transferred to moist soil. No abnormalities in behaviour, cocoon production and internal anatomy were observed that could be related to TCDD exposure.
Ref: (van Straalen et al. 1995)

Assessment

Only rudimentary summaries were available. Earthworms were unaffected by 5 mg OCDD/kg over 14 d. A longer exposure times with *Aporrectodea caliginosa* results in a NOEC of 5 mg TCDD/kg.

Collembola

Laboratory studies

Species: collembola
Test conditions: soil (0.05-10 mg OCDD/kg)
NOEC, NOEL: > 10 mg/kg soil
Ref: (van Straalen et al. 1995)
Validity: rudimentary summary
Comment: no effects on mortality or reproduction were observed.

Assessment

Only one rudimentary summary was available. The endpoints for the toxicity of OCDD on collembola lie above the tested maximum concentration of 10 mg/kg. The NOEC is therefore >10 mg/kg.

Mites

No studies found.

Beetles

Laboratory studies

Species: carabid beetle
Test conditions: soil (0.05-10 mg OCDD/kg)
Ref: (van Straalen et al. 1995)
Validity: rudimentary summary
Comment: at 0.05 mg/kg: 0% mortality and 24% reduction in feeding rate

Assessment

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

Other invertebrates

No studies found.

Soil microorganisms

The effect of TCDD on the microbial populations of a forest floor and soil was tested. No effect on the CO_2 evolution was noted at concentrations of TCDD of 0.131 mg/kg in the forest floor or 0.052 mg/kg in the forest soil.
Ref: (Kenaga et al. 1981)

The effect of TCDD on soil respiration in forest soil and litter was tested at 0.0052, 0.52, 52 ng/kg for 28 d. For the litter material, CO_2 evolution was constant over the test period and was not affected by TCDD. For the incubated soil, CO_2 evolution decreased with time and was somewhat higher in the presence of TCDD.
Ref: (van Straalen et al. 1995)

The microbial activity in soils containing 0.008-2.4 mg TCDD/kg was tested. The microbial activity and diversity and soil respiration seemed to be unaffected by TCDD.
Ref: (van Straalen et al. 1995)

Assessment

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.

Birds

Test compound	Adminis-tration	Species	Duration	LC50 μg/kg	NOEC	LC10 mg/kg	Ref.
TCDD	diet	bobwhite	8 d	0.167			(Kenaga et al. 1981)
		mallard duck	8 d			0.278	
		turkey	11 d		>0.259 μg/kg		
2,4,5-T	oral	mallard duck	19 d		2000 mg/kg		
TCDD	diet	bobwhite	18 wk		0.0003 μg/kg (reproduction)		

The total body intake of TCDD in daily dietary food giving a semi-chronic no-effect level for TCDD appears to be 2.1 μg/kg in birds.
Ref: (Kenaga et al. 1981)

Mammals

Test compound	Adminis-tration	Species	Duration	NOEC ng/kg	Ref.
TCDD	diet	rat	2 a	22	(Kenaga et al. 1981)

The total body intake of TCDD in daily dietary food giving a semi-chronic no-effect level for TCDD appears to be 0.55-5.2 μg/kg in mammals.
Ref: (Kenaga et al. 1981)

Literature

Kenaga, E. E., and L. A. Norris. 1981. Environmental Toxicity of TCDD. Paper read at 2nd International Symposium on chlorinated dioxins and related compounds, at Arlington.

van Straalen, N. M., C. A. M. van Gestel, and J. Römbke. 1995. Review of dioxin toxicity to soil organisms and terrestrial wildlife. In *Kriterien zur Beurteilung organischer Bodenkontaminationen: Dioxine (PCDD/F) und Phthalate.* Frankfurt/Main: DECHEMA.

Folpet

Usage and environmental behaviour

CAS-No: 133-07-3 (1)
Chemical group: carboximide, phthalimid
Type: Fungicide
Chemical data: log Kow 3.11 l/kg; Koc 304-1164
Selected uses: berries, flowers, ornamentals, fruits, vegetables, seed and plant bed treatment; also in paints and plastics.

Selected registered applications in Switzerland

Name of product	Content of a.i.	Application rate of the product
Phaltan 80 WDG	80%	1.6-2 l/ha
Folpet 80	80%	1.6-2 l/ha
Folpet Burri Folpet 50 Hoko	50%	2.4-3.2 l/ha

Folpet is a protective leaf-fungicide, which inhibits cell division of a broad spectrum of microorganisms. It is strongly adsorbed in soil, unlikely to leach and has a half-life in the soil of 4.3 d. Folpet has a yearly usage in Switzerland of 95 t. It has not been detected in compost, but in fruit or vegetables on the market.

Ecotoxicity

Worms

Laboratory studies

Species: *Lumbricus terrestris*
Test compound: Ortho-Phaltan 75 (Folpet 75%)
Duration: 14 d
Test conditions: soil (adults, 18/conc)
LC50: 459 mg ai/kg dry soil
Ref: (Haque et al. 1983)
Validity: test development for OECD

Species: *Eisenia fetida*
Test compound: Ortho-Phaltan 75 (Folpet 75%)
Duration: 14 d
Test conditions: soil (adults, 18/conc)
LC50: 339 mg ai/kg dry soil
Ref: (Haque et al. 1983)
Validity: test development for OECD

Species: *Tubifex tubifex*
Test compound: ortho-phaltan (folpet 80%)
Duration: 7 d
Test conditions: watery medium with a sand-soil mixture sediment, 0-1000 mg/l (20/conc)
LC50: 1.7 mg ai/l
Ref: (Högger et al. 1994)
Validity: scientific literature

Species: *Eisenia*
Duration: 14 d
Test conditions: artificial soil
LC50: 339 mg ai/kg
Ref: (Högger et al. 1994)

Validity: summary, cited as OECD 207

Field studies

No studies found.

Assessment

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

Collembola

No studies found.

Mites

No studies found.

Beetles

Laboratory studies

Species: *Coccinella septempunctata*, larvae
Test conditions: glass plates
Ref: internal database
Validity: GLP, guideline
Comment: slightly harmful at standard application rates

Species: *Coccinella septempunctata*, emerging adults from previous test
Test conditions: glass aquarium, broad bean plants
E = 45
Ref: internal database
Validity: GLP, guideline
Comment: decrease in fertility; slightly harmful at standard application rates

Field studies

No studies found.

Assessment

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 this concentration.

Other invertebrates

Laboratory studies

Species: *Typhlodromus pyri*
Test conditions: glass plates
Ref: internal database
Validity: GLP, guideline
Comment: harmless at standard application rates

Species: *Typhlodromus pyri*, surviving mites from previous test
Test conditions: in glass plates with week old treatment
Ref: internal database
Validity: GLP, guideline
Comment: harmless at standard application rates

In a rudimentary summary folpet was described as slightly harmful to *Coccinella septempunctata*, as harmless to *Poecilus cupreus*, *Trichogramma cacoeciae, Chrysoperla carnea, T. pyri, Aleochara bilineata* and *Aphidius rhopalosiphi*.
Ref: (PM)

Field studies

No studies found.

Assessment

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

Soil mircoorganisms

No studies found.

Birds

Test compound	Adminis-tration	Species	Duration	LC50 mg/kg	LD50 mg/kg	NOEC mg/kg	Ref.
Folpet		bobwhite quail		>2510			(Extoxnet)
		mallard duck		>5000			
	oral		acute	>2000			(PM)

Further acute oral studies indicated that folpet is slightly toxic to upland game bird species. Subacute dietary toxicity studies with bobwhite quail and mallard ducks also indicate that folpet is slightly toxic to birds when it is ingested in the diets of these birds. The avian reproductive studies indicate that technical folpet is not expected to cause reproductive impairment.
Ref: (Extoxnet)

Mammals

Test compound	Adminis-tration	Species	Duration	LC50/LD50 mg/kg	NOEC mg/kg	Ref.
Folpet	oral	rat	acute	>10000		(Extoxnet)
		mice		2440		
	diet	rat	3 generations		1000	(PM)

Literature

Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].

Haque, A., and W. Ebing. 1983. Toxicity determination of pesticides to earthworms in the soil substrate. *Z. PflKrankh. PflSchutz* 90:395-408.

Högger, C. H., and H. U. Ammon. 1994. Testing the toxicity of pesticides to earthworms in laboratory and field tests. *IOBC wprs Bulletin* 17:157-178.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Iprodione

Usage and environmental behaviour

CAS-No: 36734-19-7
Chemical group: dicarboximide
Type: Fungicide
Chemical data: log Kow 3 (pH 3 and 5); Koc 373-1551 l/kg
Selected uses: vegetables, ornamentals, pome and stone fruit, root crops, cotton, sunflowers

Selected registered applications in Switzerland

Name of product	Content of a.i.	Application rate of the product
Rovral	50%	0.6-1.6 kg/ha
Iprodion 500	500.6 g/l	0.6-1.6 l/ha

Iprodione has been detected in compost, as well as in fruit and vegetables on the market. It has a half-life (DT50) of 20-160 d in the soil in the field. The degradation rate increases with successive treatment; hence, accumulation does not occur. Iprodione is a contact fungicide, with protective and curative action. It inhibits germination of spores and growth of fungal mycelium.

Ecotoxicity

Worms

Laboratory studies

Species: earthworms (species not defined)
Duration: 14 d
Administration: soil
LC50: >1000 mg/kg soil
Ref: (PM)
Comment: rudimentary summary

Species: *Tubifex tubifex*
Test compound: Rovral (iprodion 50%)
Duration: 7 d
Administration: watery medium with a sand-soil mixture sediment (0-1000 mg/l; 20/conc)
LC50: 150 mg ai/l
Ref: (Högger et al. 1994)
Validity: scientific literature

Field studies

No studies found.

Assessment

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

Collembola

No studies found.

Mites

No studies found.

Beetles

No studies found.

Other invertebrates

No studies found.

Soil microorganisms

No studies found.

Birds

Test compound	Administration	Species	Duration	LD50 mg/kg	NOEC mg/kg	Ref.
Iprodione		bobwhite quail		930		(Extoxnet)
	oral	bobwhite quail	acute	>2000		(PM)
		mallard duck		>10400		

Mammals

Test compound	Administration	Species	Duration	LD50	NOEC	Ref.
Iprodione	oral	rat		3500		(Extoxnet)
		rats, mice	acute	>2000	150 mg/kg (diet, 2 y)	(PM)
		mice		4000		(Extoxnet)

Rats fed high doses of iprodione (1000 mg/kg) for a year and a half suffered no ill effects.
Ref: (Extoxnet)

Literature

Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].

Högger, C. H., and H. U. Ammon. 1994. Testing the toxicity of pesticides to earthworms in laboratory and field tests. *IOBC wprs Bulletin* 17:157-178.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Metolachlor

Usage and environmental behaviour

CAS-No: 51218-45-2
Group: acetanilide, acetamid, chloroacetamide
Type: Herbicide
Chemical data: log Kow 2.9 (25°C); Koc 121-309 l/kg;
Selected uses: field corn, soybeans, peanuts, grain sorghum, potatoes, pod crops, cotton, sunflower, stone fruits, nut trees, highway right of ways, woody ornamentals

Selected registered applications in Switzerland

Name of product	Content of a.i.	Application rate of the product
Primafit A (in combination with pendimethalin and atrazine)	200 g/l	8 l/ha

Metolachlor is a selective herbicide, which inhibits protein and chlorophyll synthesis and growth. It is mobile in soil, where it easily leaches. The half-life (DT50) in the field is 14-51 d and in the laboratory 100 d in silt.

Ecotoxicity

Worms

Laboratory studies

Species: earthworm (species not defined)
Duration: 14 d
Test conditions: soil
LC50: 140 mg/kg
Ref : (PM)
Validity: rudimentary summary

Species: *Tubifex tubifex*
Test compound: Dual (metolachlor 96%)
Duration: 7 d
Test conditions: watery medium with a sand-soil mixture (0-1000 mg/l; 20/conc)
LC50: 21 mg ai/l
NOEC, NOEL:
Ref: (Högger et al. 1994)
Validity: scientific study

Field studies

No studies found.

Assessment

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

Collembola

No studies found.

Mites

No studies found.

Beetles

Laboratory studies

Species: *Menochilus sexmaculatus* (Coccinellidae)
Test compound: metolachlor
LC50: 4726 mg/kg
Ref: (Agritox)
Validity: www database

Field studies

No studies found.

Assessment

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.

Other invertebrates

Laboratory studies

Species: *Chelonus blackburni*
Test compound: metolachlor
LC50: 1406 mg/kg
Ref: (Agritox)
Validity: www database

Species: *Bracon brevicornis*
Test compound: metolachlor
LC50: 2743 mg/kg
Ref: (Agritox)
Validity: www database

Field studies

No studies found.

Assessment

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.

Soil microorganisms

At a dose of 3.75 kg/ha no significant effect on C/N-mineralisation was observed.
Ref: (Agritox)
Validity: rudimentary summary from www database

Birds

Test compound	Adminis-tration	Species	Duration	LC50 mg/kg	LD50 mg/kg	NOEC mg/kg	Ref.
Metolachlor		mallard ducks, bobwhite quail	5 d			>10000 (survival)	(Extoxnet)
	oral	mallard ducks, bobwhite quail	acute		>2150		(PM)
	diet	mallard ducks, bobwhite quail	8 d	>10000			(PM)

Mammals

Test compound	Adminis-tration	Species	Duration	LD50	NOEC	Ref.
technical grade	oral	rat	acut	1200 - 2780		(Extoxnet), (PM)
	diet	rat	90 d		300 (15 mg/kg daily)	(PM)
	diet	mice	90 d		100	(PM)

Literature

Agritox. *http://www.inra.fr/agritox/fiches* INRA, [cited 2003].

Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].

Högger, C. H., and H. U. Ammon. 1994. Testing the toxicity of pesticides to earthworms in laboratory and field tests. *IOBC wprs Bulletin* 17:157-178.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

PAH

Usage and environmental behaviour

Chemical data: log Kow 3.27-6.7
Occurrence: burning of fossil fuel or biomass

The half-life of phenanthrene is 16-60 d and for pyrene >200 d. PAHs sorb to soil particles tightly. PAH are taken up by organisms, but are not biomagnified.

Ecotoxicity

Worms

Laboratory studies

Species: *Eisenia fetida andrei*
Test compound: benzo(a)pyrene
Duration: 14 d
Test conditions: artficial soil (0.05, 1, 100, 1000 mg/kg; 3x4 worms; adults)
Ref: (Saint-Denis et al. 1999)
Validity: standard soil test OECD 1984
Comment: different biochemical factors were evaluated as potential biomarkers, activities of catalase (CAT), acetylcholinesterase (AchE) and glutathione-S-transferase (GST) remained unchanged; the dose had a significant effect on lipid peroxidation (LP and LPI), whereas the duration of exposure significantly affected phase I enzymes; earthworms can metabolise B(a)P.

Species: *Eisenia andrei*
Test compound: benzo(a)pyrene
Duration: 28 d
Test conditions: natural soil (20, 100 mg/kg; 40 worms/conc)
NOEC, NOEL: >100 mg/kg (mortality, weight, behaviour, immune activity)
Ref: (Eason et al. 1999)
Validity: ok, biomarker development
Comment: at 20 mg/kg neutral red retention time was affected

Species: *Eisenia fetida*
Test compound: fluorene
Duration: 14 d
Test conditions: artificial soil
LC50: 173 mg/kg
Ref: (Eason et al. 1999)
Validity: summary

Species: *Eisenia fetida*
Test compound: chrysene
NOEC: 1000 mg/kg (reproduction)
Ref: (Eason et al. 1999)
Validity: summary

Species: *Eisenia veneta*
Test compound: various - see following table
Duration: 28 d
Test conditions: mixed in agricultural soil (10, 30,100, 300,1000 mg/kg; 20 worms/conc; sexually mature)
Lowest LC50: 69 mg/kg
Lowest NOEC: 26 mg/kg
Ref: (Sverdrup et al. 2002c)
Validity: controlled

Comment: Sensitivity varies with different PAHs (see table)

Test compound	LC50 (mg/kg dw)	NOEC (growth, reproduction) (mg/kg dw)
Pyrene	155	29
Fluoranthene	416	98
Phenanthrene	134	31
Fluorene	69	28

Species: *Enchytraeus crypticus*
Test compound: various - see following table
Duration: 21 d
Test conditions: agricultural soil (highest concentration for acridine 5120 mg/kg, for dibenzofuran 1280 mg/kg and 2560 for all others (nominal – corrected for volatility loss); 40/conc; sexually mature)
Lowest LC50: 400 mg/kg
Lowest NOEC: 18 mg/kg
Ref: (Sverdrup et al. 2002d)
Validity: controlled
Comment: less sensitive than springtails, toxicity significantly decreased with increasing log Kow. (acridine: strong binding to soil reduces toxicity); Sensitivity varies with different PAHs (see table)

Test compound	LC50 (mg/kg dw)	NOEC (growth, reproduction) (mg/kg dw)
Pyrene	>2300	18
Fluoranthene	>2500	38
Phenanthrene	>2000	34
Fluorene	1600	27

Species: *Eisenia fetida*
Test compound: various – see following table
Duration: 48 h
Test conditions: contact filter paper (10/conc)
Lowest LC50: 49 $\mu g/cm^2$
Ref: (Neuhauser et al. 1985)
Validity: EEC contact test

Test compound	LC50 ($\mu g/cm^2$)
Acenaphthene	49
Fluorene	171
Fluoranthene	2160
Naphthalene	4670

Species: *Eisenia fetida*
Test compound: fluorene
Duration: 14 d
Test conditions: soil (40/conc)
LC50: 173 mg/kg
Ref: (Neuhauser et al. 1985)
Validity: artificial soil test EEC

Species: various - see following table
Test compound: various - see following table
Duration: variable – see following table
Test conditions: soil (converted from μmol/g)
Lowest NOEC: 100 mg/kg
Ref: (van Brummelen et al. 1996)
Validity: quotes from other sources

Test compound	Species	EC50/LC50 (mg/kg dw)	LOEC (weight) (mg/kg dw)	NOEC (mg/kg dw)	Duration (weeks)
Fluorene	*Eisenia fetida*		748	500	8 (R)
			1500	1000	8 (S)
Phenanthrene	*Eisenia fetida*	241	321	100	3 (R)
			1000	321	3 (S)
Fluoranthene	*Enchytraeus crypticus*			>1214	(R, S)
Benzo(a)pyrene	*Eisenia fetida*		26		4 (S, R)
	Eisenia crypticus		26		4 (R)

R: reproduction; S: survival; G: growth; P: protein

In a 14 d bioassay, tests with creosote contaminated soil were conducted and compared to slurry-phase biotreated soil. Soils with low PAH:DEO (dichloromethane extractable organics) were less toxic as measured by earthworm survival times, compared to soils with higher ratios. In soils containing 1320-1500 mg PAH/kg *E. fetida* died within 1 day in bioassays.
Ref: (Charrois et al. 2001)
Validity: controlled

Field studies

No studies found.

Assessment

The toxicity of twelve different PAHs was tested on mainly 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 compounds 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 and the NOEC is 18 mg/kg. For Fluoranthene these values for the same species are 416 mg/kg and 38 mg/kg respectively.

Collembola

Laboratory studies

Species: *Folsomia fimetaria*
Test compound: pyrene and phenanthrene
Duration: 21 d
Test conditions: agricultural soil aged prior to bioassay (phenanthrene: 25-400 mg/kg;
pyrene: 7.5-120 mg/kg or 30-480 mg/kg (10 d aged) or 15-240 mg/kg (40 and 120 d aged); 80/conc)
LC50: see table
Ref: (Sverdrup et al. 2002b)
Validity: standardised bioassay from Wiles and Krogh, 1998
Comments: No reduction in toxicity was observed, even though the compounds were degraded (high test concentration). The soil had a low organic carbon content of 1.6%. Metabolites were not measured.

Test compound	LC50 (mg/kg dw)
Pyrene	44-53
Phenanthrene	30-41

Species: *Folsomia fimetaria*
Test compound: various – see following table
Duration: 21 d
Test conditions: agricultural soil (80/conc)
Lowest LC50: 21 mg/kg

Lowest NOEC: 8.6 mg/kg
Ref: (Sverdrup et al. 2001)
Validity: standardised bioassay Wiles and Krogh, 1998
Comment: light source not comparable to outside conditions (phototoxic compounds)

Test compound	LC50 (mg/kg dw)	NOEC reproduction (mg/kg dw)
Fluoranthene	81	47
Fluorene	39	14
Phenanthrene	41	21
Pyrene	53	13

Species: *Folsomia fimetaria*
Test compound: various - see following table
Duration: 21 d
Test conditions: agricultural soil (10, 30, 100, 300, 1000 mg/kg; anthracene: also 3 mg/kg; benzo(a)pyrene: 16, 32, 64, 128, 1000 mg/kg; 80/conc; 23-26 d old)
Lowest LC50: 67 mg/kg
Lowest EC10: 5 mg/kg
Ref: (Sverdrup et al. 2002a)
Validity: standardised test Wiles and Krogh, 1998

Test compound	LC50 (mg/kg dw)	EC10 (reproduction) (mg/kg dw)
Naphthalene	167	20
Acenaphthylene	145	23
Acenaphthene	107	31
Anthracene	67	5
Perylene	>560	>560
Benzo(a)pyrene	>840	>840
Indeno(1,2,3-cd)pyrene	>910	>910
Dibenz(a,h)anthracene	>780	>780
Benz(a)anthracene	>980	>980
Chrysene	>1030	>1030
Benzo(b)fluoranthene	>360	>360
Benzo(k)fluoranthene	>560	>560

Species: *Folsomia fimetaria*
Test compound: carbazole
Duration: 10 d
Test conditions: agricultural soil (0, 10, 30, 100, 300, 1000, 3000 mg/kg; 60/conc; eggs and 0-1 d juveniles)
NOEC: 300 mg/kg (no effects on egg hatching)
Ref: (Sverdrup et al. 2001)
Validity:
Comment: high sensitivity of juveniles compared to adults; at 1000 mg/kg 25% reduction in egg hatching

Species: *Folsomia candida*
Test compound: phenanthrene
Duration: 4 weeks
Test conditions: soil (converted from μmol/g)
LC50: 144 mg/kg
NOEC: 75 mg/kg (reproduction, mortality)
Ref: (van Brummelen et al. 1996)
Validity: quoted from other sources

In general springtails were more sensitive than earthworms and enchytraeids (looking at LC50).
Ref: (Sverdrup et al. 2002c)

Only PAH with reported log Kow 3.3-5.2 (naphthalene, acenaphthene, acenaphthylene, anthracene, phenanthrene, fluorene, pyrene, fluoranthene) significantly affected the survival or reproduction of the test organism *Folsomia fimetaria*.
Ref: (Sverdrup et al. 2002a)

Field studies

No studies found.

Assessment

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).

Mites

Laboratory studies

No studies found.

Field studies

Thirty soil cores contaminated with creosote were analysed for the abundance of Oribatid mites. Their abundance was correlated negatively with smaller-ring PAH (phenanthrene, fluoranthene and pyrene), but not affected by 5-ring PAH compounds, benzo(a)pyrene or an unidentified 5-ring compound.
Ref: (Blakely et al. 2002)

Assessment

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.

Beetles

No studies found.

Other invertebrates

Laboratory studies

Species: *Porcellio scaber*
Test compound: benzo(a)pyrene
Duration: 9 weeks
Test conditions: diet (0, 3.16, 10, 31.6, 100, 316 mg BaP/kg dw food; 24/conc)
NOEC: 31.6 mg/kg (according to the abstract)
Ref: (van Brummelen et al. 1993)
Validity: controlled
Comment: High mortality occurred at all concentrations and was not related to treatment. In a graph growth was already significantly affected at 10 mg/kg, but not at 31.6 mg/kg. Therefore the effects at 10 mg/kg are not considered to be dose related. At 100 mg/kg growth was reduced. At 316 mg/kg growth, survival and energy reserves were reduced.

Species: *Oniscus asellus*
Test compound: benzo(a)pyrene
Duration: 9 weeks
Test conditions: diet (0, 3.16, 10, 31.6, 100, 316 mg BaP/kg dw food; 24/conc)

NOEC: 31.6 mg/kg
Ref: (van Brummelen et al. 1993)
Validity: controlled
Comment: At 100 mg/kg growth was reduced. At 316 mg/kg growth, survival, and energy reserves were reduced.

Species: *Porcellio scaber*
Test compound: various – see following table
Duration: 16 weeks
Test conditions: petri dish with food (fluorene, phenanthrene, fluoranthene: 0.125, 0.396, 1.25, 3.96 μmol/g (nominal); benz(a)anthracene and benzo(a)pyrene: 0.0396, 0.125, 0.396, 1.25 μmol/g dry food; 60/conc)
Ref: (van Brummelen et al. 1996)
Validity: not clear why endpoints are given < max conc.
Comment: No adverse effect on survival, growth, total protein were observed.

Species: *Oniscus asellus*
Test compound: various – see following table
Duration: 47 weeks
Test conditions: petri or rectangular dish with food (fluorene, phenanthrene, fluoranthene 0.125, 0.396, 1.25, 3.96 μmol/g (nominal); benz(a)anthracene and benzo(a)pyrene: 0.0396, 0.125, 0.396, 1.25 μmol/g dry food; 60 adults/conc; 25 juveniles)
Lowest NOEC: 3 mg/kg
Ref: (van Brummelen et al. 1996)
Validity: controlled

Assessment: Adults: Survival, growth, total protein and reproduction were observed. Fluorene and benz(a)anthracene significantly affected weight (no clear relationship to concentration or time). Mortality and reproduction (time of first reproduction, proportion of broods that hatched, number of juveniles per brood, reproductive allocation) were unaffected by treatment. Phenanthrene, fluoranthene, benzo(a)pyrene did not significantly affect fresh weight (in another study weight was reduced at 1.25 μmol benzo(a)pyrene/g dw after 9 weeks).
Juveniles: Reproduction and survival of juveniles was observed. Number of juveniles per brood and survival of juveniles upon starvation was unaffected by treatment (22 d).

nominal values normalized to 10% organic matter

Test compound	Species	NOEC mg/kg	LOEC (weight) mg/kg	Duration (weeks)
Fluorene	*P. scaber*	>219		16 (G, P, S)
	O. asellus	21.9	70	47 (G)
		7	22	47 (P – females)
		>219		47 (R, S)
Phenanthrene	*P. scaber*	>235		16 (G, P)
	O. asellus	>235		47 (G, P, R, S)
Fluoranthene	*P. scaber*	>267		16 (G, P)
	O. asellus	>267		47 (G, P, R, S)
Benz(a)anthracene	*O. asellus*	3	9.6	47 (G)
		>301		47 (P, R, S)
	P. scaber	>96		16 (G, P)
Benzo(a)pyrene	*P. scaber*	>106		16 (G, P)
		10.6	33	9 (G)
		33	106	9 (P)
	O. asellus	>106		47 (G, P, R, S)
		10.6	33	9 (G)
		>106		9 (P)
		33	106	9 (S)

R: reproduction; S: survival; G: growth; P: protein

In a further study *Porcellio scaber* (110-150/conc) were exposed in pots to contaminated food with benzo(a)pyrene (0, 1, 5, 25, 125 mg/kg food) for 5 weeks. No acute toxicity or effects on food

consumption were observed. The assimilation of food increased in male isopods due to BaP (increased need for energy). Growth decreased in adult males (11% to 1.7% at 125 mg/kg) and increased in females (10% to 20.5% at 1 mg/kg).
Ref: (van Straalen et al. 1991)
Validity: scientific literature, not very good.

Increased mortality in *Oniscus asellus* and decreased protein concentration in *Porcellio scaber* at 1.25 μmol benzo(a)pyrene/g dw.
Ref: (van Brummelen et al. 1996)
Comment: Organisms kept single were more stressed than organisms in a group.

Field studies

In thirty soil cores, which were contaminated with creosote the abundance of nematodes was analysed. The abundance was affected by a number of PAHs (concentration not very clear – maturity index). Creosote is responsible for changes in ecological succession of nematodes communities. Nematodes were affected indirectly by altering the physical habitat.
Ref: (Blakely et al. 2002)

Free living soil nematodes were analysed for their total and relative abundance, their trophic and taxonomic groups, trophic and taxonomic diversity, proportion of fungivores to bacterivores nematodes in contaminated soil (total PAH 5.3 – 80.5 mg/kg, mainly 4-6 rings). PAH acted as an organic substrate for soil microbes, which in turn stimulated populations of higher trophic level organisms. High molecular weight compounds may be co-metabolized by microflora in the presence of more readily degradable carbon sources. Relative abundance of nematode trophic groups and total abundance of all trophic groups except fungivores showed significant differences between plots.
Ref: (Snow-Ashbrook et al. 1998)

Assessment

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 and phenanthrene. However, for *Oniscus asellus* the NOEC (growth) for fluorene and benz(a)anthracene was one to two orders of magnitude lower. 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.

Soli microorganisms

Laboratory studies

Species: soil nitrifying bacteria
Test compound: see table
Duration: 4 weeks
Test conditions: agricultural soil in cylinders (3x 1, 3, 10, 30, 100, 300, 1000, 3000 mg/kg dry soil – nominal values)
LC50, LD50, EC50: number of protozoans, soil nitrification – see table
NOEC, NOEL: soil nitrification - see table
Ref: (Sverdrup et al. 2002e)
Validity: standardised test ISO method 14238
Comment: No effect on bacterial diversity was observed. The effect on protozoan numbers was weak. Low PAH concentrations generally led to somewhat increased protozoan abundance, which gradually levelled off with increasing concentrations, most pronounced for the flagellates. A comparison of the sensitivity of the three microbial endpoints nitrification, protozoan number, and bacterial genetic diversity shows that the nitrification process generally is the most sensitive (apart for acridine – protozoans more sensitive). Effects on nitrification showed a significant inverse relationship with lipophility. Only the fraction of the substance that is dissolved in the pore water is available to the nitrifying bacteria.

Test compound	EC10 mg/kg (nitrification)	EC50 mg/kg (nitrification)	EC5 mg/kg (protozoa) total no	EC5 mg/kg (protozoa) flagellates	NOEC mg/kg (nitrification)
Pyrene	130				79
Fluoranthene	13			2200	24
Phenanthrene	42	250	2400	250	26
Fluorene	33	190			72
Carbazole	33				23
Dibenzothiophene	24	180	2000	1100	22
Dibenzofuran	74	200	1300	600	75
Acridine	1400	2800	380	490	1100

No value = could not be estimated

Field studies

In thirty soil cores contaminated with creosote the fungal biomass was negatively associated with the concentrations of pyrene and fluoranthene ($2.04x10^{-5}$ to $6.46x10^{-6}$ mg biomass/kg of dry soil). Bacterial populations correlated positively with increased concentrations of PAH (108 to 109 mg biomass/kg dry soil).
Ref: (Blakely et al. 2002)

Assessment

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

Literature

Blakely, J. K., D. A. Neher, and A. L. Spongberg. 2002. Soil invertebrate and microbial communities, and decomposition as indicators of polycyclic aromatic hydrocarbon contamination. *Applied Soil Ecology* 21:71-88.

Charrois, J. W. A., W. B. McGill, and K. L. Froese. 2001. Acute ecotoxicity of creosote-contaminated soils to Eisenia fetida: a survival-based approach. *Environmental Toxicology and Chemistry* 20 (11):2594-2603.

Eason, C. T., C. Svendsen, K. O'Halloran, and J. M. Weeks. 1999. An assessment of the lysosomal neutral red retention test and immune function assay in earthworms (Eisenia andrei) following exposure to chlorpyrifos, benzo-a-pyrene (BaP), and contaminated soil. *Pedobiologia* 43:641-645.

Neuhauser, E. F., R. C. Loehr, M. R. Malecki, D. L. Milligan, and P. R. Durkin. 1985. The toxicity of selected organic chemicals to the earthworm Eisenia fetida. *J. Environ. Qual.* 14 (3):383-388.

Saint-Denis, M., J. F. Narbonne, C. Arnaud, E. Thybaud, and D. Ribera. 1999. Biochemical responses of the earthworm Eisenia fetida andrei exposed to contaminated artificial soil: effects of benzo(a)pyrene. *Soil Biology and Biochemistry* 31:1837-1846.

Snow-Ashbrook, J., and K. M. Erstfeld. 1998. Soil nematode communities as indicators of the effects of environmental contamination with polycyclic aromatic hydrocarbons. *Ecotoxicology* 7:363-370.

Sverdrup, L. E., T. Nielsen, and P. H. Krogh. 2002a. Soil ecotoxicity of polycyclic armoatic hydrocarbons in relation to soli sorption, lipophilicity and water solubility. *Environmental Science and Technologie* 36:2429-2435.

Sverdrup, L. E., J. Jensen, P. H. Krogh, and J. Stenersen. 2002b. Studies on the effect of soil aging on the toxicity of pyrene and phenanthrene to a soil-dwelling springtail. *Environmental Toxicology and Chemistry* 31 (3):489-492.

Sverdrup, L. E., P. H. Krogh, T. Nielsen, and J. Stenersen. 2002c. Relative sensitivity of three terrestrial invertebrate tests to polycyclic aromatic chemical substances. *Environmental Toxicology and Chemistry* 21:1927-1933.

Sverdrup, L. E., J. Jensen, A. E. Kelley, P. H. Krogh, and J. Stenersen. 2002d. Effects of eight polycyclic aromatic chemical substances on the survival and reproduction of Enchytraeus crypticus (oligochaeta, clitellata). *Environmental Toxicology and Chemistry* 21:109-114.

Sverdrup, L. E., F. Ekelund, P. H. Krogh, T. Nielsen, and K. Johnsen. 2002e. Soil microbial toxicity of eight polycyclic aromatic compounds: effects on nitrification, the genetic diversity of

bacteria, and the total number of protozoans. *Environmental Toxicology and Chemistry* 21 (8):1644-1650.

Sverdrup, L. E., A. E. Kelley, P. H. Krogh, T. Nielsen, J. Jensen, J. J. Scott-Fordsmand, and J. Stenersen. 2001. Effects of eight polycyclic aromatic chemical substances on the survival and reproduction of the springtail Folsomia fimetaria L. (Collembola, Isotomidae). *Environmental Toxicology and Chemistry* 20:1332-1338.

van Brummelen, T. C., and S. C. Stuijfzand. 1993. Effects of benzo(a)pyrene on survival, growth and energy reserves in the terrestrial isopods Oniscus asellus and Porcellio scaber. *Sci. Tot. Environ.* supplement:921-930.

van Brummelen, T. C., C. A. M. van Gestel, and R. A. Verweiji. 1996. Long-term toxicity of five polycyclic aromatic hydrocarbons for the terrestrial Oniscus asellus and Porcellio scaber. *Environmental Toxicology and Chemistry* 15:1199-1210.

van Straalen, N. M., and R. A. Verweiji. 1991. Effects of benzo(a)pyrene on food assimilation and growth efficiency in Porcellio scaber (Isopoda). *Bull. Environ. Contam. Toxicol.* 46:134-140.

PCB

Usage and environmental behaviour

Chemical data: Bioaccumulation factors (BAF) for different congeners are between 0.34 and 24 from compost or soil to worms.
Selected uses: insulating liquids, hydraulic oil, its usage is prohibited

PCB have been detected in compost, are persistent and accumulative.

Ecotoxicity

Worms

Laboratory studies

Species: *Lumbricus terrestris*
Test compound: Aroclor 1254
Duration: 5 d
Test conditions: filter paper (2.5, 5, 10, 40, 50, 100, 200, 400, 800 μg/cm^2; adult)
LC50: 300 μg/cm^2
LD50: 1140 mg/kg dry tissue mass
Ref: (Rodriguez-Grau et al. 1989)
Validity: bioassay development
Comment: moderately toxic; Suppression of immune system (S-rosette) at 5.0 μg/cm^2 or 76 mg/kg dry tissue mass.

Species: *Eisenia fetida*
Test compound: Aroclor 1254
Duration: 5 d
Test conditions: filter paper (2.5, 5, 6.25, 10, 12.5, 25, 50, 75, 100 μg/cm^2; 10-40/conc)
LC50: 30.4 μg/cm^2
LD50: 4500 mg/kg dry tissue mass
Ref: (Fitzpatrick et al. 1992)
Validity: scientific literature, controlled
Comment: *E. fetida* accumulated more than *L. terrestris* and showed lower LC50, but higher LD50 and exhibited effects on coelomocytes (~immunesystem) only at tissue PCB concentrations that caused some mortality. *E.fetida* appears more resistant to chemical toxicity than *L. terrestris*.

Arochlor 1254 caused a significant reduction in the total immune activity of earthworm (*Eisenia veneta*) at 0.49 mg/ml.
Ref: (Bunn et al. 1996)
Validity: scientific literature

In *Lumbricus terrestris* exposed for 120 h to 10 μg PCB/cm^2 (91 mg/kg dry tissue mass) phagocytosis by coelomocytes was reduced by 65%.
Ref: (Giggleman et al. 1998)
Validity: scientific literature

Assessment

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 μg/cm^2 (30 kg/ha, 40 mg/kg according to the criteria in scenario II) for *L. terrestris* and 30.4 μg/cm^2 (3.04 kg/ha, 4 mg/kg according to the criteria in scenario II) for *E. fetida*.

Collembola

Laboratory studies

Species: *Folsomia candida*
Test compound: PCB 153
Duration: 28 d
Test conditions: artificial soil (0, 81.8, 204, 491 mg/kg)
NOEC: 204 mg/kg (mortality, reproduction)
Ref: (Stämpfli 2001)
Validity: guideline ISO
Comment: the test at 491 mg/kg was not carried out in replicate and can therefore not confidently be included in the result.

Field studies

No studies found.

Assessment

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

Mites:

No studies found.

Beetles:

No studies found.

Other invertebrates

Laboratory studies

Species: *Chorthippus brunneus*
Test compound: Arochlor 1254
Duration: no information
Test conditions: topical (12.5, 50, 200 μg/insect; fourth instar nymphs)
Ref: (Dobson et al. 1993)
Validity: WHO publication
Comment: No effects on development and reproductive potential. Mortality could not be assessed as the mortality figures were unreliable due to a fungal infection. At the highest concentration moulted males died – males showed 46% mortality and females 41% after treatment with 200 μg Arochlor 1254.

Species: *Drosophila melanogaster*
Test compound: Aroclors 1221, 1232, 1242, 1248 (separately)
Duration: 48 h
Test conditions: 200, 800 μg/vessel or insect
NOEL: 200 μg/vessel or insect
Ref: (Dobson et al. 1993)
Validity: WHO publication
Comment: Unit not clear. At 800 μg there was an increase in mortality with decreasing degree of chlorination.

Species: *Drosophila melanogaster*
Test compound: Aroclors 1254, 1260, 1262, 1268 (separately)
Duration: 48 h
Test conditions: 2000 μg/vessel or insect
Ref: (Dobson et al. 1993)
Validity: WHO publication
Comment: Unit not clear; No effects

Species: *Acrobeloides nanus*
Test compound: Aroclor 1254
Duration: 10 d
Test conditions: petridish (15, 30, 60 μg per dish with 20 nematodes)
Ref: (Dobson et al. 1993)
Validity: WHO publication
Comment: at 15 μg/petri dish number of adults, eggs and weight reduced; in a previous study no adverse effects were observed at 60 μg/petri dish after 5 d.

On a low Calcium diet the snail *Cepeae nemoralis* bores holes into the shell of other snails. The addition of PCB (Aroclor 0.5-5 mg/kg) increased the penetration. PCB also damaged the shells (not only penetration).
Ref: (Dobson et al. 1993)
Validity: WHO

Field studies

No studies found.

Assessment

Eight different mixtures of PCB congeners were used for the toxicity studies with two different groups of invertebrates (two insects and one nematod species). The information is 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 is given about the mixture composition. The shells from snails were damaged by 0.5 mg/kg.

Soil microorganisms

Mycelial growth of *Aspergillus flavus* was reduced to 1.4-54.6% of control levels by Aroclor 1232,1242,1248,1254,1260 at 25 mg/l in liquid culture medium and at the same time the relative RNA content of the mycelium increased. DNA was not affected. The number of cells of soil the alga *Navicula pelliculosa* was reduced by Aroclors 1016,1221,1242,1248 at 20 μg/l after 2 d.
Ref: (Dobson et al. 1993)
Validity: WHO publication

Assessment

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

Birds

Test compound	Administration	Species	Duration	LC50 mg/kg	LD50 mg/kg	Ref.
Aroclor 1242 - 1254	oral	mallard duck	acute		> 2000	(Yu-Cheng 1994)
Aroclor 1232 - 1262	diet	bobwhite quail	5 d		500	
Aroclor 1232 - 1262	diet	japanese quail	5 d		5000	
Aroclor 1554	oral	bengalese finches	56 d		254	
Aroclor 1232, 1242, 1248, 1254, 1260, 1262	diet	pheasant		1100-3200		(Hansen 1987)
		bobwhite quail		600-30000		
		japanese quail		2200-5000		

Birds tend to be less resistant (acutely) to higher chlorinated PCBs
Ref: (Hansen 1987)

In short-term tests, toxicity of Aroclor for birds increased with increasing percentage of chlorination. The 5-d dietary LC50 ranged from 604 to >6000 mg/kg diet. The main reproductive effects of PCBs on birds were reduced hatchability of eggs and embryotoxicity. These effects continued after dosing ended, as the hens reduced their PCB load via the eggs. Aloclor causes egg-shell thinning through reduced food consumption and body weight. Sub-lethal effects on behaviour and hormone secretion have been reported.
Ref: WHO

Field studies

The most prevalent effect observed in the field is reproductive impairment, including embryotoxicity and aberrant parental incubation behaviour. Selected endpoints were adverse changes in the community structure and reproductive impairment. In a polluted area with 0.5-32 mg PCB/kg soil and 6-200 mg/kg sediments the diversity, reproduction, and hatchability seemed normal.
Ref: (Henning et al. 1995)

Interpretation of field data on birds is difficult, since residues of many different organochlorines are also present. Most authors have shown a correlation between effects (embryotoxicity) and total organochlorine residues. Of the organochlorine compounds present, PCB residues correlate best with the effects on embryos, but the results cannot be regarded as proved field effects of the PCBs.
Ref: WHO

Mammals

Test compound	Administration	Species	Duration	LD50 mg/kg	Ref.
Aroclors 1221 – 1262 - 1254	intravenous/oral	rat	acut	4000 – 11300 – 358	(Yu-Cheng 1994)
2,4,3,4-tetrachlorobiphenyl	intraperitoneal	mice	acut	2150	

Literature

Bunn, K. E., H. M. Thompson, and K. A. Tarrant. 1996. Effects of agrochemicals on the immune systems of earthworms. *Bull. Environ. Contam. Toxicol.* 57:632-639.

Dobson, S., and G. J. van Esch. 1993. Polychlorinated biphenyls and terphenyls. Geneva: World Health Organisation.

Fitzpatrick, L. C., R. Sassani, B. J. Venables, and A. J. Goven. 1992. Comparative toxicity of polychlorinated biphenyls to earthworms Eisenia foetida and Lumbricus terrestris. *Environmental Pollution* 77:65-69.

Giggleman, M. A., L. C. Fitzpatrick, A. J. Goven, and B. J. Venables. 1998. Effects of pentachlorophenol on survival of earthworms (Lumbricus terrestris) and phagocytosis by their immunnoactive coelomocytes. *Environmental Toxicology and Chemistry* 17:2391-2394.

Hansen, L. G. 1987. Environmental toxicology of polychlorinated biphenyls. In *Polychlorinated biphenyls (PCBs): mammalian and environmental toxicology.*, edited by S. Safe and O. Hutzinger. Berlin: Springer.

Henning, M. H., E. S. Ebert, E. R. Algeo, and R. E. Keenan. 1995. Assessment of effects of PCB-contaminated sediments and floodplain soils on reproduction and community structure of insectivorous song birds. In *Toxicology, ecotoxicology, mechanism of action, metabolism*, edited by L. Birnbaum. Edmonton, Alberta: DIOXIN '95 Secretariat.

Rodriguez-Grau, J., and B. J. Venables. 1989. Suppression of secretory rosette formation by PCBs in Lumbricus terrestris: an earthworm assay for humoral immunotoxicity of xenobiotics. *Environmental Toxicology and Chemistry* 8:1201-1207.

Stämpfli, C. 2001. Etude des relations entre l'exposition de folsomia candida à un micropollutant organique et les effets observés à différents niveaux d'organisation biologique: utilité des biomarqueurs comme outil prévisionnel., École Polytechnique Fédérale de Lausanne, Lausanne.

Yu-Cheng. 1994. Experimental studies on the effects of PCBs and PCTs. In *PCB toxicology, human toxicology, toxicology, ecotoxicology.* Kyoto: Kyoto University.

Phthalate

Usage and environmental behaviour

Chemical group: esterified benzenedicarboxylic acid with two alkyl chains
Chemical data: DEHP (di(2-ethylhexyl) phthalate) has a low water solubility, a high Kow (7.5) and therefore a high accumulation in soil or organisms. DBP (dibutyl phthalate) has an intermediate log Pow. DEP (diethyl phthalate): Kow 2.38, DIBP (diisobutylphthalate) log Pow 4.11.
Selected uses: plasticizers (PVC), paint, lacquer, printing ink, adhesives, fillers, dielectric fluid capacitors, food packaging and insect repellent

Phthalates have been detected in compost, drainage water from household waste sites and groundwater. The toxicity of DBP was reduced when soil spiked with it was stored at 20°C for 28d, but the concentration did not decrease to zero. The modelled half-life in soil was >30 d. In soil it slowly biodegrades with 66-98% degraded in 182 d from two soils. DEHP is easily degraded under aerobic conditions (half-lives 33 or 85 d in soil initially containing 21'900 mg/kg), but not under anaerobic conditions. DEP has a half-life of 0.75 d at 20°C (0.1 mg/g). The rate and extent of biodegradation of DEP decreased with increasing concentration (at 10 mg/g 29 d). 10% of DEHP degraded by 70 d at 20°C. Phthalates are metabolised and excreted by higher organisms (fish, humans) and earthworms. They are not taken up by plants via soil, but rather through deposition from air. A few phthalates may disrupt the endocrine system of vertebrates.

Ecotoxicity

Worms

Laboratory studies

Species: 4 earthworm species
Test compound: dimethyl phthalate
Duration: 14 d
Test conditions: soil
LC50: 1064-3335 mg/kg
Ref: (Jensen et al. 2001)
Validity: EU artificial soil test

Species: *Eisenia fetida*
Test compound: dimethyl phthalate
Duration: 14 d
Test conditions: soil (40/conc)
LC50: 3160 mg/kg
Ref: (Neuhauser et al. 1985)
Validity: artificial soil test EEC

Species: *Eisenia fetida*
Test compound: see table
Duration: 48 h
Test conditions: contact filter paper (10/conc)
LC50: see table (average: 1760 $\mu g/cm^2$)
Ref: (Neuhauser et al. 1985)
Validity: EEC contact test

Test compound	Administration	LC50 ($\mu g/cm^2$)	Ref.
Dimethylphthalate	Contact	550	(Neuhauser et al. 1985)
Diethylphthalate		850	
n-Butylphthalate		1360	
Dioctylohthalate		3140	
Bis(2-ethylhexyl)phthalate		> 25'000	

Field studies

No studies found.

Assessment

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 *E. 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 *E. 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.

Collembola

Laboratory studies

Species: *Folsomia fimetaria*
Test compound: di(2-ethylhexyl) phthalate (DEHP)
Duration: 21 d
Test conditions: sandy soil (adults (23-26 d): 4x 0, 1000, 2000, 3000, 4000, 5000 mg/kg dw; juveniles: 0, 100, 250, 500, 1000 mg/kg dw; 20 /conc)
Ref: (Jensen et al. 2001)
Validity: controlled
Comment: no adverse effects observed

Species: *Folsomia fimetaria*
Test compound: dibutyl phthalate (DBP)
Duration: 21 d
Test conditions: sandy soil (4x 0, 100, 250, 500, 750, 1000 mg/kg dw; 20/conc; adults 23-26 d)
EC50: 68 mg/kg (reproduction –for 21 d)
LC50: 277 mg/kg
Ref: (Jensen et al. 2001)
Validity: controlled; in some of the tests mortality in control samples exceeded 20%, which lessened the certainty of the test results.

Species: *Folsomia fimetaria*
Test compound: dibutyl phthalate (DBP)
Duration: 42 d
Test conditions: sandy soil (0, 1, 5, 10, 25 mg/kg dw; 20 juvenile 0-1 d)
LC50: 19.4 mg/kg
Ref: (Jensen et al. 2001)
Validity: controlled, but high variability in data and therefore confusing; at 25 mg/kg all dead within 1 d; survived at 10 mg/kg for 1 week; at 1 mg/kg number of cuticles was significantly reduced.

The effect of storage on the toxicity of DBP was investigated in the laboratory. The toxicity was reduced if the contaminated soil was stored for 1-2 weeks before exposure. The measured total concentration of DBP in the 500 mg/kg assay was still 265 mg/kg 28 d after addition. Although this concentration is similar to the LC50 value of 277 mg/kg in the assays with no storage, no mortality could be detected in soil stored for 28 d.
Ref: (Jensen et al. 2001)

Field studies

No studies found.

Assessment

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 the reproduction of adults was more sensitive than the survival. The EC50 of adults was 68 mg/kg and the LC50 277 mg/kg. All juveniles died within 1 d at 25 mg/kg. The LC50 was 19.4 mg/kg and the NOEC <1 mg/kg.

Mites

No studies found.

Beetles

Laboratory studies

Species: *Musca domestica*
Test compound: DIBP
Test conditions: abdomen or intrathoracal; 20 μg DIBP/fly (equivalent to 1000 mg/kg body weight; 3 d old)
Ref: (BUA 1997)
Validity: rudimentary summary
Comment: no adverse effects were observed

Species: *Musca domestica*
Test compound: 17 phthalates
Duration: 24 h
Test conditions: topically or injection (20 μg/insect (equivalent to 1000 mg/kg body weight); 20/conc; 3 d old)
Ref: (Al-Badry et al. 1980)
Validity: scientific literature
Comment: No adverse effects were observed, mortality <15%. Synergistic interaction if pre-treated with DEHP followed by organophosphate. Antagonistic interaction with simultaneous application of DEHP and 21 organophosphates.

Field studies

No studies found.

Assessment

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

Other invertebrates

No studies found.

Soil microorganisms

Soil incubations in bottles were carried out with sandy clay loam, whose surface was treated with phthalate. DEP + DEHP at 100 mg/kg had no impact on the structural diversity (bacterial numbers, fatty acid methyl ester analysis) or functional diversity of the microbial community over 28 d; DEP >1000 mg/kg reduced numbers of both total culturable bacteria (by 47%) and pseudonmonas (by 62%) within 1 d for 16 d; DEHP at 100'000 mg/kg had no impact on microbial community. DEHP could be degraded by *Comamonas acidovorans* (60% in 15 d), DEP was not degraded as a sole carbon source. Impact of DEP and DEHP (100 mg/kg) on the soil community is expected to be minimal as no long-term effect was observed. DEHP is predicted to be incorporated into the organic matter of the soil. Smaller molecular mass phthalates (relative molecular mass < 320) were predicted to be a potentially greater environmental risk, although rapid biodegradation means that they will not persist in the environment. At >1000 mg/kg significant impact on the microbial community and environmental processes mediated by it can be expected.
Ref: (Cartwright et al. 2000)
Validity: scientific literature, not comprehensible, with errors.

50'000 mg DIBP/kg inhibited soil respiration in not preincubated soil.
Ref: (BUA 1997)

Assessment

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.

Literature

Al-Badry, M. S., and C. O. Knowles. 1980. Phthalate-organophosphate interactions: toxicity, penetration, and metabolism studies with house flies. *Archives of Environmental Contamination and Toxicology* 9:147-161.

BUA. 1997. *Diisobutylphthalat*. Edited by Beratergremium für umweltrelevante Altstoffe der Gesellschaft Deutscher Chemiker: Hirzel.

Cartwright, C. D., I. P. Thompson, and R. G. Burns. 2000. Degradation and impact of phthalate plasticizers on soil microbial communities. *Environmental Toxicology and Chemistry* 19 (5):1253-1261.

Jensen, J., J. van Langevelde, G. Pritzl, and P. H. Krogh. 2001. Effects of di(2-ethylhexyl) phthalate and dibutyl phthalate on the collembolan Folsomia fimetaria. *Environmental Toxicology and Chemistry* 20:1085-1091.

Neuhauser, E. F., R. C. Loehr, M. R. Malecki, D. L. Milligan, and P. R. Durkin. 1985. The toxicity of selected organic chemicals to the earthworm Eisenia fetida. *J. Environ. Qual.* 14 (3):383-388.

Polybrominated diphenylethers (PBDE)

Usage and environmental behaviour

Chemical data: high bioaccumulation
Used in: plastic, textiles as flame retardant

It has not been detected in compost yet, but in sewage sludge. It slowly degrades in soil.

Ecotoxicity

Worms

No studies found.

Collembola

No studies found.

Mites

No studies found.

Beetles

No studies found.

Other invertebrates

No studies found.

Soil microorganisms

No studies found.

Aquatic organisms

No studies are available with PBDE. MBDE (monobromodiphenylether) is (strongly) toxic to aquatic organisms.

Procymidone

Usage and environmental behaviour

Chemical group: Dicarboximide
Type: Fungicide
Chemical data: log Kow 3.1(26°C)

Selected registered applications in Switzerland

Not registered in Switzerland.

Procymidone is a systemic fungicide and inhibitor of triglyceride synthesis in fungi. It has not been detected in compost, but in fruits and vegetables on the market. Its half-life (DT50) in soil is 28-84 d. It is absorbed by plants through roots with translocation to leaves and flowers.

Ecotoxicity

Worms

No studies found.

Collembola

No studies found.

Mites

No studies found.

Beetles

No studies found.

Other invertebrates

No studies found.

Soil microorganisms

No studies found.

Mammals

Test compound	Administration	Species	Duration	LD50 mg/kg	NOEC mg/kg	Ref.
Procymidone	oral	rat	acute	6800 (male), 7700 (female)	1000 (male), 300 (female) (2 y)	(PM)

Literature

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Thiabendazole

Usage and environmental behaviour

CAS-No: 148-79-8
Chemical group: benzimidazole
Type: Fungicide
Chemical Data: log Kow 2.4 l/kg (pH 7)
Selected uses: fruit and vegetables and for treatment of roundworms in livestock

Selected registered applications in Switzerland

Name of product	Content of a.i.	Application rate of the product
Tecto flowable	450 g/l	0.35 ml/kg
Drawipas	1%	Wundverschlussmittel

Thiabendazole is a systemic fungicide. It inhibits mitosis by binding to tubuline and thus severely impairs fungal growth and development. Thiabendazole has been measured in compost, fruit and vegetables on the market. It strongly adsorbes in acidic soil, where it is quite persistent (after 9 months 85-98% residue). The half-life (DT50) is 33-120 d. No leaching is expected. It is readily absorbed by plants in the roots and translocated to all parts of a plant, but predominantly to the leaf margins.

Ecotoxicity

Worms

Laboratory studies

Species	Administration	LC50 mg/kg	LD50 µg/worm	NOEC mg/kg reproduction	Ref.
Eisenia fetida	soil	>1000		4.2	(Agritox)
worms			20		(Extoxnet)
worms	soil	>500			(PM)

Field studies

No studies found.

Assessment:

Only rudimentary summaries were found about the toxicity of thiabendazole to worms. The EC50 for worms is >500 mg/kg soil and the NOEC (reproduction) is 4.2 mg/kg soil.

Collembola

No studies found.

Mites

No studies found.

Beetles

No studies found.

Other invertebrates

Laboratory studies

Species	Dose kg/ha	Fecundity effect %	Mortality	E-value	Ref.
Aleochara bilineata	0.9	27	none	27	(Agritox)
Aphidius rhopalosiphi	1.8	62	none	62	
Chrysoperla carnea	1.8	27	4%	30	
Typhlodromus pyri	1.8	5	3	8	

Field studies

No studies found.

Assessment

Thiabendazole is harmless to *Aleochara bilineata*, *Chrysoperla carnea* and *T. 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.

Soil microorganisms

At a dose of 9 mg/kg no significant effects on C/N-mineralisation were observed.
Ref: (Agritox)
Validity: www database

Birds

Test compound	Adminis-tration	Species	Duration	LC50 mg/kg	LD50 mg/kg	Ref.
Thiabendazole	oral	bobwhite quail	acute		>2250	(PM)
	diet	bobwhite quail, mallard ducks	5 d	>5620		

Mammals

Test compound	Adminis-tration	Species	Duration	LD50 mg/kg	NOEC mg/kg/day	Ref.
Thia-bendazole	oral	rat	acute chronic	3100-3600 1200	200	(Extoxnet)
	feed	rat	2 a		40	(PM)
	oral	mice		1395-2810 mg/kg		(Extoxnet)

Rats force-fed 200 mg/kg/d or less showed little or no growth effects. At higher levels 400 mg/kg there was growth suppression. Death occurred in a few days at 1200 mg/kg and 30% mortality occurred within 30 d at 800 mg/kg. A three generation study in rats showed no adverse effects on reproduction at 20-80 mg/kg.
Ref: (Extoxnet)

Literature

Agritox. *http://www.inra.fr/agritox/fiches* INRA, [cited 2003].
Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].
PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Trifluralin

Usage and environmental behaviour

CAS-No: 1582-09-8
Chemical group: dinitroaniline
Type: Herbicide
Chemical data: log Pow 5.1 (4.8), Koc 4400-40000 l/kg
Selected uses: fruit trees, nuts, vegetables, grain crops

Selected registered applications in Switzerland

Name of product	Content of a.i.	Application rate of the product
Trifluralin	480 g/l	25 + 30 g/ha 2-3 l/ha
Triherbin	480 g/l	2-3 l/ha

Trifluralin has been detected in compost, but not in fruit or vegetables on the market. It does not move much in soil, as it strongly absorbes in soils. Trifluralin is nearly insoluble in water. Different half-lives are found in the literature with 45-60 d, 57-126 d or 6-8 months (2.5 kg/ha). After 6-12 months 80-90% of its activity will be gone. Anaerobic degradation is faster. It does not show a significant absorption or translocation in crops. It is a selective herbicide, which is used pre-emergence.

Ecotoxicity

Worms

Laboratory studies

Species: *Tubifex tubifex*
Test compound: trifluralin 48%
Duration: 7 d
Test conditions: watery medium with a sand-soil mixture sediment (0-1000 mg/l; 20/conc)
LC50: 50 mg ai/l
Ref: (Högger et al. 1994)
Validity: scientific publication

Species: *Eisenia fetida*
Duration: 14 d
Test conditions: soil
LC50: >1000 mg/kg dry soil
Ref: (PM), (Agritox)
Validity: rudimentary summary
Comment: at 171 mg/kg body weight reduced.

100 mg/kg are toxic to earthworms.
Ref: (Extoxnet)
Validity: www database

Field studies

No studies found.

Assessment

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

Collembola

No studies found.

Mites

No studies found.

Beetles

No studies found.

Other invertebrates

Laboratory studies

Two experiments were carried out:
A (uptake experiment) - In model chambers filled with silty sand soil earthworms, springtails, aphids, isopods and gall gnats (20 or 30 test species) were exposed for 4 weeks to trifluralin. The isopoda *Porcellio scaber* accumulated trifluralin and its metabolites with body concentrations (BCF value) from 7-19 times those in litter and topsoil, earthworms accumulated 7x more than isopods.
B - *Porcellio scaber* isopods were fed on trifluralin treated (2.5 l Elancolan/ha and 200.5 l/ha) litter of black cherry and alder in petri dishes for 3 weeks. No effects on feeding, defaecation rates, weight development and mortality at recommended application rates (mortality always ~30%) were observed. No indication that *Porcellio scaber* changes its food consumption in relation to the level of trifluralin contamination of the food.
Ref: (Staak et al. 1998)
Validity: scientific literature, method development, bioaccumulation study
Comment: substrate exposure maybe more critical than dietary exposure.

Field studies

No studies found.

Assessment

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

Soil microorganisms

A - microcosm experiments: Soil was mixed with the herbicide and cotton seeds coated with test bacteria were planted in the soil. Each experiment was carried out in five replicas. The application of each of the test herbicides at the rates of 1, 2 and 4 mg ai/kg soil caused significant ($p<0.05$) reductions in populations of most of the isolates in the rhizosphere 14 d after the release of bacteria into the soil by seed coating. All (5) isolates (root colonizing bacteria, *Burkholderia cepacia, Pseudomonas fluorescens*) are efficient cotton root colonizers and each is capable of suppressing a plant disease.
B - In a time experiment 1.8 mg a.i./kg soil were mixed with the soil and 1, 2, 3 and 4 weeks after the release of bacteria, the bacteria were counted. The ability of the herbicide to reduce the bacterial population in the rhizosphere declined with time over a 4-wk period of monitoring. (in wk 3 and 4 similar to control)
C – In field experiments with 4 replicas 0.7 kg a.i./ha were mixed into the soil. Seeds and bacteria were added by soil drenching. After 15, 25 and 50 days bacteria were counted. Trifluralin had no or only after 25 d an effect on bacteria (reduction not very obvious). Maybe the isolate (recovered from cotton fields) had developed a tolerance.
Ref: (Heydari et al. 1997)
Validity: scientific literature, controlled

Trifluralin at 0.5 μg/g (mg/μg or μg/ml) dry soil to 5 μg/ml dry soil (species dependant) appeared to stimulate the growth of soil bacteria, actinomycetes, mould, and the pure cultures of nitrogen-fixing bacteria *Bradyrhizobium japonicum* and *Azotobacter chroococcum* (number, size and growth rate of colonies increased). Trifluralin at higher concentrations (200 μg/ml and 400 μg/ml) would inhibit the development of microbial colonies both in amount and size. But it seems that soil

microorganisms could use trifluralin as sole carbon and nitrogen resources for their growth. Trifluralin had no selection effect on soil bacteria, actinomycete and mould. The experiments were carried out in tubes (anaerobic medium + aerobic trifluarlin + soil) and petri dishes.
Ref: (Hang et al. 2001)
Validity: scientific literature, badly written, not conclusive and contradictions in units

Assessment

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.

Birds

Test compound	Administration	Species	Duration	LC50 mg/kg	LD50 mg/kg	Ref.
Trifluralin	oral	bobwhite quail	acute		> 2000	(Extoxnet) (PM)
	diet	quail, mallard ducks	5 d	> 5000		(Extoxnet) (PM)

Mammals

Test compound	Administration	Species	LD50	Ref.
technical trifluralin	oral	rat	> 10000	(Extoxnet)
	oral	mice	> 5000	
	oral	dogs, rabbit, chicken	> 2000	

Rats, dietary, 10 mg/kg: unimpaired reproductive capacity through 4 successive generations, no abnormalities detected in parents or offspring; 100 mg/kg to pregnant rabbits and 225 mg/kg to rats had no adverse effect on offspring or mothers.
Ref: (Extoxnet)

Literature

Agritox. *http://www.inra.fr/agritox/fiches* INRA, [cited 2003].

Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].

Hang, M., C. Zhongyun, Z. Yuhua, and C. Meichi. 2001. Effects of trifluralin on soil microbioal populations and the nitrogen fixation activities. *J. Environ. Sci. Health* B36 (5):569-579.

Heydari, A., I. J. Misaghi, and W. B. McCloskey. 1997. Effects of three soil-applied herbicides on populations of plant disease suppressing bacteria in the cotton rhizophere. *Plant and Soil* 195:75-81.

Högger, C. H., and H. U. Ammon. 1994. Testing the toxicity of pesticides to earthworms in laboratory and field tests. *IOBC wprs Bulletin* 17:157-178.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Staak, A., M. Frost, and W. Kratz. 1998. Ecotoxicological studies on the impact of the herbicide trifluralin on Porcellio scaber (Isopoda). *Applied Soil Ecology* 9:405-409.

Vinclozolin

Usage and environmental behaviour

CAS No: 50471-44-8
Chemical group: Dicarboximid
Type: Fungicide
Chemical data: log Kow 3.0 (ph 7); Koc 100-735 l/kg
Selected uses: vineyards, fruit (strawberries), vegetables, ornamentals

Selected registered applications in Switzerland

Name of product	Content of a.i.	Application rate of the product
Ronilan	50%	1.6 l/ha

Vinclozolin is a non-systemic, contact fungicide that inhibits spore germination. It has not been detected in compost yet, but in fruit or vegetables on the market. Vinclozolin is rather persistent in soil and only partially broken down by microorganisms. The half-life (DT50) is several weeks.

Ecotoxicity

Worms

Laboratory studies

Species: *Tubifex tubifex*
Test compound: Ronilan (vinclozolin 41.3%)
Duration: 7 d
Administration: watery medium with a sand-soil mixture sediment (0-1000 mg/l; 20/conc)
LC50: 520 mg ai/l
Ref: (Högger et al. 1994)
Validity: summary in a scientific publication

Field studies

No studies found.

Assessment

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

Collembola

No studies found.

Mites

No studies found.

Beetles

Laboratory studies

Three tests with Ronilan 50 WP (0.1% vinclozolin) with *Adalia bipunctata* were found: 1) Individuals (30/conc) were immersed for 5 s in the pesticide solution (0.5 ml ai/l) and then reared for 7 d in glass containers. Vinclozolin was harmful to first and second instar larvae (control not shown) and the percent of hatched larvae eggs decreased slightly. 2) The second and fourth instar larvae (30/conc) were placed on leaves picked from trees treated with the pesticide and observed for 7 d. The exposure started 2 h, 3, 7, 14, 21, 28 d after the trees were treated (0.8 l ai/ha, with density of 25 lb/ft^3 this is equivalent to 0.32 kg ai/ha). 7 d after treatment the mortality increased (control not shown) 3) Adult coccinellids (10/conc) were fed with aphids contaminated by a recommended concentration of the pesticide. The coccinellid fecundity decreased.

Ref: (Olszak 1999)
Validity: scientific literature, elaborated, but not controlled

Field studies

No studies found.

Assessment

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.

Other invertebrates

No studies found.

Soil microorganisms

Soil samples from rice field were inoculated with *Proteus vulgaris, Proteus* sp.*, Micrococcus* sp. and treated with Ronilan (50% W/W vinclozolin) at doses of 10, 100, 1000 mg ai/kg. The observation time was 56 d. At the lowest concentration tested negative effects occurred on bacteria, fungi and Actinomycets. A recovery was not apparent over eight weeks. Urea hydrolysis in culture and soil were also inhibited. Effects on growth of urea-hydrolyzing bacteria were observed. The fungicide inhibited cell wall formation and lipid metabolism.
ID50 (concentration at which urea hydrolysis is inhibited by 50%): 370 mg/l (*Micrococcus* sp), 477 mg/l (*Proteus* sp.), 382 mg/l (*Proteus vulgaris*).
Ref: (Banerjee et al. 1991)
Validity: scientific literature

Assessment

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.

Birds

Test compound	Administration	Species	Duration	LD50 mg/kg	Ref.
Vinclozolin	oral	bobwhite quail	acute	>2510	(Extoxnet) (PM)
		bobwhite quail		>5620	(PM)

Mammals

Test compound	Administration	Species	Duration	LD50 mg/kg	Ref.
Vinclozolin		rat	acute	>10000	(Extoxnet)
	oral	rat, mice	acute	>15000	(PM)

Birth defects at 73 mg/kg in rats.
Ref: (Extoxnet)

Literature

Banerjee, A., and A. K. Banerjee. 1991. Effect of the fungicides tridemorph and vinclozolin on soil microorganiosms and nitrogen metabolism. *Folia Microbiol.* 36 (6):567-571.

Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].

Högger, C. H., and H. U. Ammon. 1994. Testing the toxicity of pesticides to earthworms in laboratory and field tests. *IOBC wprs Bulletin* 17:157-178.

Olszak, R. W. 1999. Influence of some pesticides on mortality and fecundity of the aphidophagous coccinellid Adalia bipunctata L. (Col., Coccinellidae). *J. Appl. Ent.* 123:42-45.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Ecotoxicological Literature

Agritox. *http://www.inra.fr/agritox/fiches* INRA, [cited 2003].

Al-Assiuty, A. I. M., and M. A. Khalil. 1996. Effects of the herbicide atrazine on Entomobrya musatica (Collembola) in field and laboratory experiments. *Applied Soil Ecology* 4:139-146.

Al-Badry, M. S., and C. O. Knowles. 1980. Phthalate-organophosphate interactions: toxicity, penetration, and metabolism studies with house flies. *Archives of Environmental Contamination and Toxicology* 9:147-161.

Anton, F., E. Laborda, and P. Laborda. 1990. Acute toxicity of the fungicide captan to the earthworm Eisenia foetida (Savigny). *Bull. Environ. Contam. Toxicol.* 45:82-87.

Badejo, M. A., and N. M. van Straalen. 1992. Effects of atrazine on growth and reproduction of Orchesella cincta (collembola). *Pedobiologia* 26:221-230.

Bale, J. S., M. Ekebuisi, and C. Wright. 1992. Effect of seed bed preparation, soil structure and release time on the toxicity of a range of grassland pesticides to the carabid beetle Pterostichus melanarius (Ill.) (Col., Carabidae) using a microplot technique. *J. Appl. Ent.* 113:175-182.

Banerjee, A., and A. K. Banerjee. 1991. Effect of the fungicides tridemorph and vinclozolin on soil microorganiosms and nitrogen metabolism. *Folia Microbiol.* 36 (6):567-571.

Belden, J. B., and M. J. Lydy. 2000. Impact of atrazine on organophosphate insecticide toxicity. *Environmental Toxicology and Chemistry* 19 (9):2266-2274.

Blakely, J. K., D. A. Neher, and A. L. Spongberg. 2002. Soil invertebrate and microbial communities, and decomposition as indicators of polycyclic aromatic hydrocarbon contamination. *Applied Soil Ecology* 21:71-88.

Booth, L. H., and K. O'Halloran. 2001. A comparison of biomarker responses in the earthworm aporrectodea caliginosa to the organophosphorus insecticides diazinon and chlorpyrifos. *Environmental Toxicology and Chemistry* 20 (11):2494-2502.

Brust, G. E. 1990. Direct and indirect effects of four herbicides on the activity of carabid beetles (Coleoptera: carabidae). *Pesticide Science* 30:309-320.

BUA. 1997. *Diisobutylphthalat*. Edited by Beratergremium für umweltrelevante Altstoffe der Gesellschaft Deutscher Chemiker: Hirzel.

Bunn, K. E., H. M. Thompson, and K. A. Tarrant. 1996. Effects of agrochemicals on the immune systems of earthworms. *Bull. Environ. Contam. Toxicol.* 57:632-639.

Cartwright, C. D., I. P. Thompson, and R. G. Burns. 2000. Degradation and impact of phthalate plasticizers on soil microbial communities. *Environmental Toxicology and Chemistry* 19 (5):1253-1261.

Chang, Y. J., A. K. M. A. Hussain, J. R. Stephen, M. D. Mullen, D. C. White, and A. Peacook. 2001. Impact of herbicides on the abundance and structure of indigenous β–subgroup ammonia-oxidizer communities in soil microcosms. *Environmental Toxicology and Chemistry* 20 (11):2462-2468.

Charrois, J. W. A., W. B. McGill, and K. L. Froese. 2001. Acute ecotoxicity of creosote-contaminated soils to Eisenia fetida: a survival-based approach. *Environmental Toxicology and Chemistry* 20 (11):2594-2603.

Chen, S.-K., C. A. Edwards, and S. Subler. 2001a. A microcosm approach for evaluating the effects of the fungicides benomyl and captan on soil ecological processes and plant growth. *Applied Soil Ecology* 18:69-82.

———. 2001b. Effects of the fungicides benomyl, captan and chlorothalonil on soil microbial activity and nitrogen dynamics in laboratory incubations. *Soil Biol. Biochem.* 33:1971-1980.

Ciglar, I., and B. Baric. 2000. Side effect of some fungicides on the mite population in an apple orchard in Croatia. *J. Pest Science* 73:110-112.

Colinas, C., E. Ingham, and R. Molina. 1994. Population responses of target and non-target forest soil organisms to selected biocides. *Soil Biol. Biochem.* 26 (1):41-47.

Cowles, R. S., and M. G. Villani. 1994. Soil interaction with chemical insecticides and nematodes used for control of Japanese beetle (Coleoptera: Scarabaeidae) larvae. *Entomological Society of America* 87 (4):1014-1021.

Crommentuijn, T., J. A. Stäb, A. Doornekamp, O. Estoppey, and C. A. M. van Gestel. 1995. Comparative ecotoxicity of cadmium, chlorpyrifos and triphenyltin hydroxide for four clones of the parthenogenetic collembola Folsomia candida in an artificial soil. *Functional Ecology* 9:734-742.

Curtis, J. E., and P. A. Horne. 1995. Effect of chlorpyrifos and cypermethrin applications on non-target invertebrates in a conservation-tillage crop. *J. Aust. ent. Soc.* 34:229-231.

Dobson, S., and G. J. van Esch. 1993. Polychlorinated biphenyls and terphenyls. Geneva: World Health Organisation.

Eason, C. T., C. Svendsen, K. O'Halloran, and J. M. Weeks. 1999. An assessment of the lysosomal neutral red retention test and immune function assay in earthworms (Eisenia andrei) following exposure to chlorpyrifos, benzo-a-pyrene (BaP), and contaminated soil. *Pedobiologia* 43:641-645.

Extoxnet. *http://pmep.cce.cornell.edu/profiles/extoxnet* Cornell University, [cited 2003].

Fitzpatrick, L. C., R. Sassani, B. J. Venables, and A. J. Goven. 1992. Comparative toxicity of polychlorinated biphenyls to earthworms Eisenia foetida and Lumbricus terrestris. *Environmental Pollution* 77:65-69.

Frampton, G. K. 1999. Spatial variation in non-target effects of the insecticides chlorpyrifos, cypermethrin and pirimicarb on Collembola in winter wheat. *Pesticide Science* 55:875-886.

Gevao, B., C. Mordaunt, K. T. Semple, T. G. Peiearce, and K. C. Jones. 2001. Bioavailability of nonextractable (bound) pesticide residues to earthworms. *Environmental Science and Technologie* 35:501-507.

Giggleman, M. A., L. C. Fitzpatrick, A. J. Goven, and B. J. Venables. 1998. Effects of pentachlorophenol on survival of earthworms (Lumbricus terrestris) and phagocytosis by their immunnoactive coelomocytes. *Environmental Toxicology and Chemistry* 17:2391-2394.

Hang, M., C. Zhongyun, Z. Yuhua, and C. Meichi. 2001. Effects of trifluralin on soil microbioal populations and the nitrogen fixation activities. *J. Environ. Sci. Health* B36 (5):569-579.

Hansen, L. G. 1987. Environmental toxicology of polychlorinated biphenyls. In *Polychlorinated biphenyls (PCBs): mammalian and environmental toxicology.*, edited by S. Safe and O. Hutzinger. Berlin: Springer.

Haque, A., and W. Ebing. 1983. Toxicity determination of pesticides to earthworms in the soil substrate. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 90:395-408.

Heimbach, F. 1984. Correlations between three methods for determining the toxicity of chemicals to earthworms. *Pesticide Science* 15:605-611.

———. 1985. Comparison of laboratory methods, using Eisenia foetida and Lumbricus terrestris, for the assessment of the hazard of chemicals to earthworms. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 92 (2):186-193.

Henning, M. H., E. S. Ebert, E. R. Algeo, and R. E. Keenan. 1995. Assessment of effects of PCB-contaminated sediments and floodplain soils on reproduction and community structure of insectivorous song birds. In *Toxicology, ecotoxicology, mechanism of action, metabolism*, edited by L. Birnbaum. Edmonton, Alberta: DIOXIN '95 Secretariat.

Heydari, A., I. J. Misaghi, and W. B. McCloskey. 1997. Effects of three soil-applied herbicides on populations of plant disease suppressing bacteria in the cotton rhizophere. *Plant and Soil* 195:75-81.

Högger, C. H., and H. U. Ammon. 1994. Testing the toxicity of pesticides to earthworms in laboratory and field tests. *IOBC wprs Bulletin* 17:157-178.

Hoy, J. B., and P. J. Shea. 1981. Effects of lindane, chlorpyrifos and carbaryl on a california pine forest soil arthropod community. *Environ. Entomol.* 10:732-740.

Ingham, E. R., and D. C. Coleman. 1984. Effects of streptomycin, cycloheximide, fungizone, captan, carbofuran, cygon, and PCNB on soil microorganisms. *Microb. Ecol.* 10:345-358.

Jensen, J., J. van Langevelde, G. Pritzl, and P. H. Krogh. 2001. Effects of di(2-ethylhexyl) phthalate and dibutyl phthalate on the collembolan Folsomia fimetaria. *Environmental Toxicology and Chemistry* 20:1085-1091.

Kaakeh, N., W. Kaakeh, and G. W. Bennett. 1996. Topical toxicity of imidacloprid, fipronil, and seven conventional insecticides to the adult convergent lady beetle (Coleoptera: Coccinellidae). *J. Entomol. Sci.* 31 (3):315-323.

Kenaga, E. E., and L. A. Norris. 1981. Environmental Toxicity of TCDD. Paper read at 2nd International Symposium on chlorinated dioxins and related compounds, at Arlington.

Ma, W.-C., and J. Bodt. 1993. Differences in toxicity of the insecticide chlorpyrifos to six species of earthworms (Oligochaeta, Lumbricidae) in standarised soil tests. *Bull. Environ. Contam. Toxicol.* 50:864-870.

Martens, D. A., and J. M. Bremmer. 1997. Inhibitory effects of fungicides on hydrolysis of urea and nitrification of urea nitrogen in soil. *Pesticide Science* 49:344-352.

Martinez-Toledo, M. V., V. Salmeron, and J. Gonzalez-Lopez. 1992. Effect of the insecticides methylpyrimifos and chlorpyrifos on soil microflora in an agricultural loam. *Plant and Soil* 147:25-30.

Mola, L., M. A. Sabatini, B. Fratello, and R. Bertolani. 1987. Effects of atrazine on two species of collembola (Onychiuridae) in laboratory tests. *Pedobiologia* 30:145-149.

Mostert, M., A. S. Schoeman, and M. van der Merwe. 2000. The toxicity of five insecticides to earthworms of the Pheretima group, using an artificial soil test. *Pest Management Science* 56:1093-1097.

Mostert, M. A., A. S. Schoeman, and M. van der Merwe. 2002. The relative toxicities of insecticides to earthworms of the Pheretima group (Oligochaeta). *Pest Management Science* 58:446-450.

Nair, G. A., A. I. Mohamed, and M. H. Haeba. 2002. Laboratory studies on the LD50 of the woodlouse, Porcellio scaber Latreille (Isopoda, Oniscidea) exposed to chlorpyrifos (Dursban). *Afr. J. Ecol.* 40:393-395.

Neuhauser, E. F., R. C. Loehr, M. R. Malecki, D. L. Milligan, and P. R. Durkin. 1985. The toxicity of selected organic chemicals to the earthworm Eisenia fetida. *J. Environ. Qual.* 14 (3):383-388.

Oehlmann, J., U. Schulte-Oehlmann, M. Tillmann, and B. Markert. 2000. Effects of endocrine disruptors on prosobranch snails (Mollusca: Gastropoda) in the laboratory. Part I: Bisphenol A and octylphenol as xeno-estrogens. *Ecotoxicology* 9 (6):383-397.

Olszak, R. W. 1999. Influence of some pesticides on mortality and fecundity of the aphidophagous coccinellid Adalia bipunctata L. (Col., Coccinellidae). *J. Appl. Ent.* 123:42-45.

Percich, J. A., and J. L. Lockwood. 1978. Interaction of atrazine with soil microorganisms: population changes and accumulation. *Can. J. Microbiol.* 24:1145-1152.

PM. *The Pesticide Manual*. Edited by C. D. S. Tomlin. 12 ed. Farnham, Surrey: British Crop Protection Council.

Popovici, I., G. Stan, V. Stefan, R. Tomescu, A. Dumea, A. Tarta, and F. Dan. 1977. The influence of atrazine on soil fauna. *Pedobiologia* 17:209-215.

Rapoport, E. H., and L. Sanchez. 1968. Effect of organic fungicides on the soil microfauna. *Pedobiologia* 7:317-322.

Rodriguez-Grau, J., and B. J. Venables. 1989. Suppression of secretory rosette formation by PCBs in Lumbricus terrestris: an earthworm assay for humoral immunotoxicity of xenobiotics. *Environmental Toxicology and Chemistry* 8:1201-1207.

Saint-Denis, M., J. F. Narbonne, C. Arnaud, E. Thybaud, and D. Ribera. 1999. Biochemical responses of the earthworm Eisenia fetida andrei exposed to contaminated artificial soil: effects of benzo(a)pyrene. *Soil Biology and Biochemistry* 31:1837-1846.

Snow-Ashbrook, J., and K. M. Erstfeld. 1998. Soil nematode communities as indicators of the effects of environmental contamination with polycyclic aromatic hydrocarbons. *Ecotoxicology* 7:363-370.

Springett, J. A., and R. A. J. Gray. 1992. Effect of repeated low doses of biocides on the earthworm Aporrectodea caliginosa in laboratory culture. *Soil Biol. Biochem.* 24 (12):1739-1744.

Staak, A., M. Frost, and W. Kratz. 1998. Ecotoxicological studies on the impact of the herbicide trifluralin on Porcellio scaber (Isopoda). *Applied Soil Ecology* 9:405-409.

Stämpfli, C. 2001. Etude des relations entre l'exposition de folsomia candida à un micropollutant organique et les effets observés à différents niveaux d'organisation biologique: utilité des biomarqueurs comme outil prévisionnel., École Polytechnique Fédérale de Lausanne, Lausanne.

Sverdrup, L. E., T. Nielsen, and P. H. Krogh. 2002a. Soil ecotoxicity of polycyclic armoatic hydrocarbons in relation to soli sorption, lipophilicity and water solubility. *Environmental Science and Technologie* 36:2429-2435.

Sverdrup, L. E., J. Jensen, P. H. Krogh, and J. Stenersen. 2002b. Studies on the effect of soil aging on the toxicity of pyrene and phenanthrene to a soil-dwelling springtail. *Environmental Toxicology and Chemistry* 31 (3):489-492.

Sverdrup, L. E., P. H. Krogh, T. Nielsen, and J. Stenersen. 2002c. Relative sensitivity of three terrestrial invertebrate tests to polycyclic aromatic chemical substances. *Environmental Toxicology and Chemistry* 21:1927-1933.

Sverdrup, L. E., J. Jensen, A. E. Kelley, P. H. Krogh, and J. Stenersen. 2002d. Effects of eight polycyclic aromatic chemical substances on the survival and reproduction of Enchytraeus crypticus (oligochaeta, clitellata). *Environmental Toxicology and Chemistry* 21:109-114.

Sverdrup, L. E., F. Ekelund, P. H. Krogh, T. Nielsen, and K. Johnsen. 2002e. Soil microbial toxicity of eight polycyclic aromatic compounds: effects on nitrification, the genetic diversity of bacteria, and the total number of protozoans. *Environmental Toxicology and Chemistry* 21 (8):1644-1650.

Sverdrup, L. E., A. E. Kelley, P. H. Krogh, T. Nielsen, J. Jensen, J. J. Scott-Fordsmand, and J. Stenersen. 2001. Effects of eight polycyclic aromatic chemical substances on the survival and reproduction of the springtail Folsomia fimetaria L. (Collembola, Isotomidae). *Environmental Toxicology and Chemistry* 20:1332-1338.

Tu, C. M. 1991. Effect of some technical and formulated insecticides on microbial activities in soil. *J. Environ. Sci. Health* B26 (5+6):557-573.

van Brummelen, T. C., and S. C. Stuijfzand. 1993. Effects of benzo(a)pyrene on survival, growth and energy reserves in the terrestrial isopods Oniscus asellus and Porcellio scaber. *Sci. Tot. Environ.* supplement:921-930.

van Brummelen, T. C., C. A. M. van Gestel, and R. A. Verweiji. 1996. Long-term toxicity of five polycyclic aromatic hydrocarbons for the terrestrial Oniscus asellus and Porcellio scaber. *Environmental Toxicology and Chemistry* 15:1199-1210.

van Straalen, N. M., and R. A. Verweiji. 1991. Effects of benzo(a)pyrene on food assimilation and growth efficiency in Porcellio scaber (Isopoda). *Bull. Environ. Contam. Toxicol.* 46:134-140.

van Straalen, N. M., C. A. M. van Gestel, and J. Römbke. 1995. Review of dioxin toxicity to soil organisms and terrestrial wildlife. In *Kriterien zur Beurteilung organischer Bodenkontaminationen: Dioxine (PCDD/F) und Phthalate.* Frankfurt/Main: DECHEMA.

Wiles, J. A., and G. K. Frampton. 1996. A field bioassay approach to assess the toxicity of insecticide residues on soil to collembola. *Pesticide Science* 47:273-285.

Yu-Cheng. 1994. Experimental studies on the effects of PCBs and PCTs. In *PCB toxicology, human toxicology, toxicology, ecotoxicology.* Kyoto: Kyoto University.