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Distribution of Low Organochlorine Residues in a Woodland Ecosystem

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Organochlorines (OC) play an important part in our environment now as before. Although observing a decreasing trend in concentration in the northern hemisphere for chlorinated pesticides, we have to realise that polychlorinated biphenyls (PCBs) are still a dominant contaminant (Loganathan and Kannan 1994). For assessing residues under ecotoxicological aspects we have to consider questions concerning distribution and accumulation. Less information is available for lipophilic compounds in terres- trial foodwebs, especially in woodland ecosystems (Winter and Streit 1992). Furthermore data from areas with low contamination are scarce.
The aim of this study was to represent the distribution of OC in plants and animals of different trophic levels from a woodland ecosystem. No strict accumulation from one level to the next could be seen: especially plants showed PCB concentrations which were comparably higher. However, small carnivorous mammals were more contaminated than small herbivorous ones (Drescher-Kaden and Hutterer 1981). With the pattern of residues one can demonstrate some links between consumers. The investigation area can be defined as a low contaminated "reference area".

MATERIALS AND METHODS

For this investigation we sampled animals and plants from a woodland area in Schleswig-Holstein, Germany (10.20 E, 54.10 N). Following species were investigated: Vertebrates - Common shrew (Sorex araneaus, n=12), Pygmy shrew (Sorex minutus, n=3), Yellow necked mouse (Apodemus flavi-

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collis, n=12), Bank vole (Clethrionomys glareolus, n=12); invertebrates - isopods (Porcellio spec., 2 pools, each n=20), beetles (Carabus spec., 2 pools, each n=5), earthworms (Lumbricus rubellus and Dendrobaena octaedra, 2 pools, each n=7; animals lived without food for one day), snail (Arion spec., n=l); plants - different fractions of litter (pools of beech, Fagus silvatica): leaves, seedshells, seeds; needles of spruce (Picea abies). Samples were collected during the period autumn 1991 till autumn 1993. All samples were dried and homogenized. For the vertebrates we used carcasses.

Samples were carefully dried at 40° C to constant weight and then homogenized. An aliquot was extracted with acetone/n-hexane (1:l) for 8 h with a Soxhlet apparatus. After evaporation fat was weighed, dissolved in cyclo-hexane/ethylacetate (1:l) and separated by gel-permeation-chromatography (Biobeads SX3, 200-400 mesh). Extract was cleaned up by silica-gel-chromatography (silica gel 60, 60-230 mesh). Samples were measured with an ECD after separation on a capillary column (SE 54) and analyzed for PCB (IUPAC #):28, 52, 84, 110, 118, 128, 138, 149, 153, 170, 180, 183, 187, 194; 4,4'DDT, 4,4'DDE, 4,4'DDD, alpha-HCH, beta-HCH, gamma-HCH, HCB. Detection limits for 1 g material were 0.01 mg/kg (extractable lipid). For controlling the results subsamples were analyzed on a second column (RTX 200). As an internal standard we used Aldrin: recovery was more than 85% for Aldrin just as for the other OC measured with a OC spiked subsample. Statistical analysis was performed with SAS. Values are given in dry weight concentrations unless stated otherwise.

RESULTS AND DISCUSSION

As shown in Table 1 the PCB residues vary in plant samples only by the factor 2. All samples show some conformities: PCB #28 is the highest concentrated congener (12-16 ng/g), #177 the lowest concentrated one (0.02-1.22 ng/g). But there are some remarkable differences: #52 is relatively highly concentrated in leaves and seeds (7.0 resp. 12.9 ng/g), #149 and especially #118 (4.7 ng/g) in seedshells and needles.

Within the HCH isomers lindane dominates in beech samples (8.58 ng/g in seeds), while needles contain comparable residues of lindane (18.65 ng/g) and alpha-HCH (19.85). Beta-HCH shows only low concentrations.

The concentrations of PCBs are relatively homogenous in

Table 1. OC residues in samples of different trophic levels. Values are given in ng/g dry matter. s.d.= standard deviation. Σ-HCH= (alpha+beta+gamma); Σ-DDT= (4,4'DDT + 4,4'DDE). C. shrew= Common shrew; P. shrew= Pygmy shrew; Y.-n. mouse= Yellow-necked mouse.

	Σ -13PCB	Σ -HCH	Σ -DDT	HCB
Leaves	47.5	5.7	3.9	0.3
Seedshell	27.4	6.1	2.2	0.1
Seeds	59.8	12.1	2.4	1.0
Needles	32.0	38.5	10.5	1.6
Worms	28.5	7.5	3.1	0.6
Isopods	20.9	2.1	1.7	0.2
Beetles	23.7	1.6	2.9	0.0
Snail	2.6	1.7	0.4	0.3
C. shrew	32.7	2.5	0.5	0.1
s.d.	25.1	1.2	0.6	0.0
P. shrew	58.6	3.7	1.2	0.2
s.d.	5.3	1.5	0.5	0.1
Y.-n. mouse	8.4	2.4	1.5	0.2
s.d.	6.8	2.4	1.4	0.2
Bank vole	8.9	1.7	1.2	0.3
s.d.	11.4	0.6	2.3	0.3

Table 2. OC residues in samples of different trophic levels. Values are given in mg/kg w.w.= wet weight or lipid weight. Compare Table 1.

	Σ -13 PCB	Σ -HCH	Σ -DDT	HCB
w. w.				
Leaves	0.01	0.001	0.001	0.000
Seedshell	0.02	0.004	0.002	0.000
Seeds	0.05	0.010	0.002	0.001
Needles	0.01	0.008	0.002	0.000
lipid				
Worms	0.28	0.07	0.03	0.006
Isopods	0.22	0.02	0.02	0.002
Beetles	0.16	0.01	0.02	0.000
Snail	0.02	0.01	0.00	0.001
C. shrew	0.98	0.07	0.01	0.003
P. shrew	0.94	0.06	0.02	0.003
Y.-n. mouse	0.17	0.04	0.03	0.004
Bank vole	0.24	0.05	0.03	0.006

all invertebrate samples, only the snail sample shows 1/10 lower concentrations (Table 1) resp. 1/50 (Table 2). Also with exception of the snail the OC pesticides are comparably highly concentrated in the other invertebrates. Lindane is more highly concentrated than the other HCH isomers. Worms show the highest concentrations with 5.13 ng/g. In worms DDT and DDE show comparably high concentrations (1.36 and 1.17 ng/g resp.); the concentration of DDT in the other samples was below detection limit.

In Yellow-necked mice and Bank voles almost all PCB congeners are concentrated significantly lower than in Common shrews (Table l), while Pygmy shrews (n=3) contain residues in the same range. PCB # 138, 153 and 180 play an important part in PCB contamination; herbivorous mammals show higher residues of #118 than carnivorous ones. Only Bank voles show higher concentrations of #28. Male Yellow-necked mice were (statistically not significant) higher contaminated with PCBs than females and some congeners are comparably high as in shrews (#128, 183, 187). It may be that females reduce contamination via lactation or pregnancy.
HCB, DDE and DDT in all 4 invertebrates show comparable patterns and concentrations (Table 1 and 2). Also HCH isomers are comparably highly concentrated in small mammals: α-HCH is relatively low concentrated while lindane dominated with concentrations around 2 ng/g dry weight. Concerning the OC pesticides there are no appreciable differences between herbivorous and carnivorous mammals.

It is well known, that usually small ground living mammals are lower contaminated than other mammals of the same region, for example bats (Drescher-Kaden und Hutterer 1981). Table 3 shows some results from areas which are relatively uncontaminated. The samples from our region are even less contaminated (see Table 2). This is true for plant samples, too. From these results we can draw the conclusion, that soil is likewise low contaminated, because Bush et al. (1986) were able to demonstrate, that plantstake up most of the contamination via soil. Although we did not measure the input from the atmosphere we may draw the conclusion that the atmosphere is low contaminated, too, because of good correlations between animal contamination and atmospheric input:" ...An ecosystem subjected to high inflow of chlorinated hydrocarbons from the air will contain animals with high pollution load..." (Larsson et al. 1990)

Table 3. Residues of OC in plant and animal samples cited from different authors. sp.= species; Microt.= Microtus; w.w= wet weight; homog.= homogenate; R.= Reference.

Spezies	PCB	DDE	HCB	γ-HCH	mg/kg	Organ	R
Sorex sp.	2.97	0.65	0.03	0.63	lipid	carcass	1
Clethrio-nomys sp.	2.95	0.49	0.03	0.20	-"-	-"-	"
Apodemus sp.	2.34	0.60	0.06	0.13	-"-	-"-	"
Arvicola terrestris	0.5-2.4	--	--	--	-"-	muscle	2
Sorex araneus	10-1100	1-400	--	8-200	-"-	carcass	3
Clethrion. + Microt. sp.	8-110	0.1-80	--	--	-"-	-"-	"
Arion ater	0.7-2.2	--	--	--	-"-	homog.	2
Lumbricus terrestris	0.7-14	--	--	--	-"-	-"-	"
Aeschna sp.	--	2-80	--	0.5-80	-"-	-"-	3
Pinus strobus	0.01	--	--	--	w.w.	bark	4
Betula sp.	0.03	--	--	--	w.w.	-"-	"
Lythrum salicaria	1.39	--	--	--	w.w.	leaves	5

Ref.: 1) Drescher-Kaden, Hutterer (1981); 2)Odsjö (1976); 3) Larsson et al. (1990); 4) Hermanson, Hites (1990); 5) Bush et al. (1986).

So we can draw the conclusion that the Bornhöved area is a low contaminated "reference area". This is true for OC and heavy metals and refers to limnic and terrestrial ecosystems (Scharenberg et al. 1994; Scharenberg and Ebeling 1996).

There are no extreme differences in concentrations within different trophic levels; only mice and the snail sample contain extrem low residues. Although small carnivorous mammals were contaminated higher than herbivorous ones, no strict accumulation is obvious among the other samples concerning lipid weight or dry weight concentrations (Table 1 and 2). Especially plant samples are higher contaminated than herbivorous animals such as mice, worms or isopods (Table 1). This is obvious for Yellow-necked mice which feed intensively on beech seeds in our area (Bock, pers. comm.). Even the differences between invertebrates and shrews give no hint of any significant accumulation but in relation to lipid weight concentrations shrews are the highest contaminated animals and are slightly higher contaminated than invertebrates.

We know that OC accumulation is dependend on different parameters like food consumption, food composition and species specific physiology. It has not been our aim to demonstrate all these different types of influence but to demonstrate the OC residue situation in different trophic levels of an uncontaminated area. Concerning the pattern we can recognize some foodweb relations: besides the 3 relatively highly concentrated PCBs # 138, 153, 180 concentration of # 52 is high in shrews, beetles and worms, while #118 and especially #28 is relatively unimportant. In plant samples and Bank voles #28, 52 and 118 are higher concentrated. Isopods show their own pattern with low concentrations of #28, 52 and 118. But #28 only in plant samples is the dominant congener. Patterns in worms and in the snail have the best conformity with patterns in plants. Between the 4 different vertebrate species there are no good conformities in PCB pattern.

Also OC pesticides show no strict accumulation via trophic levels. There are higher concentrations in shrews than in mice, but high concentrations can be recognized in worms and plants, too. Because of the metabolic capacity of animals DDE is higher concentrated than DDT. In plant samples (seeds and leaves) we recognized the opposite situation.

Winter and Streit (1992) were able to demonstrate bioaccumulation for PCB #153 via leaf -caterpillar -tidmouse in a field study: the authors measured residue relations of 1 : 10 : 170. In our study for PCB #153 (dry weight) we can find for the foodchain leaf - (herbivorous beetle not measured) beetle - shrew the relation of 1 : 4 : 7 and for all PCBs the relation of 1 : 0.5 : 0.7. Fagerström (1991) is in doubt about the concept of bioaccumulation from one trophic level to the next, because too many parameters have to be considered to be constant; but this is not the way nature works. Also Guttke et al. (1988) were not able to measure any accumulation via soil - springtails - carabids.

We can recognize a tendency of accumulation - shrews are the highest contaminated animals - but our results do not present consequent bioaccumulation in higher trophic levels.

It was not possible to answer the question whether we have to expect damage because of the measured concentrations. It seems to be improbable. For example, Batty et al. (1990) recognized effects in mice (e.g. low body weight, higher organ weights or reduced reproduction rates) in a field experiment at PCB concentrations 100 times higher than concentrations in our study. Immune-suppresive effects in rats occur at PCB doses (Smialowicz et al. 1989) which were higher by orders of magnitude than residues in food of vertebrates from Bornhöved. Leonards etal. (1995) estimatedthe reproductive toxicity for minks (Mustela vison) for PCB #153 at 1.2 ng/g fresh weight; shrew of our investigation contained concentrations of 0.02 ng/g. But we have to consider the problem of transferring experimental data (Connell (1985): "...The clinicopathologic syndrome is different in each species of animals; different species vary in their susceptibility to intoxication ...").

HCB concentrations in soil (LC 50 for worms and EC 50 for plants) were estimated to be higher than 1000 mg/kg dry weight: the values for lindane were 210 and 66,5 resp. (Rudolph und Boje 1986). These high values seem quite unrealistic for Bornhöved soils (see above). But we have to consider synergistic effects of different contaminants, so only investigations for several years in the same ecosystem can give information about ecotoxicological consequences.

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