Mass balance of the POP pollution of Austrian forests and comparison with emission data

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Introduction

Mass balances have been widely used to give an overview of the fate of the emissions of semivolatile organic compounds in the environment [1-5]. As a concequence of these calculations soil has been identified as a major sink for semivolatile organic compounds. 46 % of Austria is covered by forests. Due to the size of this area, the pollutant filtering properties of forest canopy and the accumulating properties of forest soil the Austrian forests should represent an important sink for semivolatile organic compounds. Therefore the load of such substances in two major compartments, namely forest soil and the green biomass of forest canopy of Austria, was estimated using concentration data of an investigation of Austrian remote forest sites [6].

Methods

The needle and forest soil concentrations used for the calculations stem from samples of 25 forest sites far away from settlements, factories and roads. Forest soils and needles close to sources show clearly higher concentrations. Therefore calculations on the basis of this data are likely to underestimate the amount of semivolatile organic compounds actually bound in these compartments. Detailed information on the mode of calculation and underlying considerations are given in a previous paper of a corresponding estimate for PCDD/F [5].

Results and Discussion

Representing just 46 % of total Austrian area, the Austrian forest soil contains an amount of PCB, HCB and DDX which is several times higher than the current annual Austrian emission of these substances (table 1). The same has been shown for PCDD/F, too [5]. Accumulation due to persistence of the compounds, higher emissions in former years, an inadequate estimate of possible sources and input coming from transboundary air pollution are seen as reasons for these differences. Higher emissions in former years are likely to be the case for all

three compounds. Regulatory measures in Austria widely restricted the use of PCB, HCB and banned DDT several years ago. However, it is assumed that the enormous discrepancy between the HCB masses in the green biomass of forest canopy (total green biomass which represents several year old needles of coniferous trees, too, and annual increment) or soil and the annual emission cannot be attributed to the consequences of regulatory measures alone but to an inadequate estimate of sources. Calculations of annual emissions based on data of HCB use neglect the fact that this compound is emitted by various industrial and incineration processes, too. Moreover, there are strong indications of transboundary transport of air masses as additional reason for the HCB concentrations detected [7].

It is remarkable that the Austrian forest soil still contains an amount of DDX twice as high as the annual use of DDT in the early eighties of this century, which were the last years DDT was used in Austria. DDX are to a markedly higher amount present in the forest soil than the other investigated semivolatile organohalogens (table 1). However, this is not the case for the forest canopy. The enormous difference between DDX in soil and forest canopy (table 1) which cannot be attributed to different physico-chemical properties of DDX compared to the other compounds and the results for five thoroughly investigated sites [6] clearly indicate a decrease of the DDX input in Austria during the last years. Since DDT is prohibited in Austria, the recently detectable amount bound in the forest canopy is likely to stem from long-range transboundary air pollution. In particular the results for DDX clearly show the necessity as well as the success of its ban in Austria.

The amount of lindane found in forest soil or needle-/leaf-biomass of forest canopy represents a small fraction of the annual use of this pesticide in Austria. Due to regulatory measures the annual amount of lindane used in Austria can be attributed to the treatment of seeds. The results obtained from the α-HCH/γ-HCH ratios support the assumption that the lindane detected in the green biomass of forest canopy origins from lindane use in Austria or closely adjacent regions [7]. Since the agricultural soil of Austria contains less than 10 % of the annual Austrian lindane use, too [6], it remains unclear in which environmental compartments the missing amount of lindane is to be found. It is assumed that metabolism as well as volatilisation and transfer to different compartments (groundwater, atmosphere) are responsible for this result. This is likely to be so since the amount of lindane in forest soil is just a little higher than the one in forest canopy (table 1).

About one half of the annual Austrian emission of PAH is stored in the Austrian forest soil. The forest canopy contains a small fraction of the annual emission (table 1). Photochemical and other processes of decomposition, transfer and volatilisation processes are seen as main reasons why in comparison to other compounds the forest soil contains less PAH than the annual emission. This is expected to be the case for the more volatile PAHs. The balance becomes worse if benzo(a)pyrene, a less volatile and better accumulating PAH, is taken into consideration. The amount of BaP in forest soil is similar to the annual Austrian emission of this compound (table 1). Austrian forest and agricultural soil together contain about six times the annual Austrian emissions of BaP [6]. The clearly higher amounts of BaP in Austrian agricultural soils compared to forest soils might be influenced by the fact that the agricultural soil data used for calculations represent sites close to settlements and conurbations, too, which show clearly higher BaP concentrations. However, the forest soil data represent background areas.

Table 1: Estimate of PCB, lindane, HCB, DDX, PAH and BaP in soil and canopy of the Austrian forests and comparison to emission data

	PCB[2]	lindane	HCB	DDX[3]	PAH[4]	BaP[5]
	kg	kg	kg	kg	t	t
forest soil Austria (3.9 Mio. ha, 46 % of Austria)	2500	290	120	8500	215	11
needle/leaf biomass of canopy of the Austrian forests (1993)		180-240	22-30	13-17	3.2-4.2	
needle/leaf biomass increment of the Austrian forests during growing period 1993		34-69	4.3-8.5	2.5-4.9	0.6-1.2	
Austrian annual emission[1]	264	14000	1	≈0	458	14
Austrian emission during a growing period[1]					6.3	

[1] emission data: PAH, BaP in 1994 [8]
HCB, PCB in 1990 [9], for a comparison of the calculated sum of PCB in forest soil represented by the sum of PCB according to [2] the annual emission of all PCB was divided by the empirical factor 5
lindane in 1993 [10]

[2] Σ of PCB 28, PCB 52, PCB 101, PCB 138, PCB 153, PCB 180

[3] Σ of p,p'- and o,p'-DDT, p,p'- and o,p'-DDE, p,p'- and o,p'-DDE

[4] Σ of triphenylene, benzo(e)pyrene, coronene and the 16 „priority pollutant PAH" according to EPA without naphthalene

[5] benzo(a)pyrene

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