Compound-determined interrelations with regard to the POP load of Austrian background forest sites

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Introduction

A lot of investigations deal with the combined load of several persistent organic pollutants in various environmental compartments. It is, however, quite rare that statistical procedures are used to give an account of the interrelations between the concentrations of investigated compounds [1-6]. This information is very useful since it allows an in-depth characterization of the detected multi-pollutant load, an identification of associated pollutants as well as possible common origins and fates of investigated compounds. The present paper deals with such a characterization for the concentrations of PCDD/F, PCB (Σ of PCB 28, 52, 101, 138, 153, 180), HCH (Σ of α, β, γ, δ, ε), HCB, DDX (Σ of p,p'-, o,p'-DDT, -DDE, -DDD), PAH (Σ of 18 PAH including 15 EPA-PAH) and lead in spruce needles and humus layer of 25 Austrian background forest sites.

Methods

A description of investigated sites, sampling and chemical analytical methods is given in [7,8]. The Pearson correlation coefficents (r) were calculated (limit for significance $p<0.05$). Prior to these calculations not normally distributed variables were log-transformed to achieve normal distribution (please note log-scaling in some scatterplots). Regression analysis was done after verifying that assumptions had not been violated. In addition, principal component analysis – a multivariate statistical tool to identify a small number of factors that can be used to describe relationships among several variables - was made. An examination of the results of the correlation matrices, Kaiser-Meyer-Olkin-measure and Bartlett-test of sphericity revealed a good factor solution only for the data of the humus layer. To make the principal components more interpretable the initial factor matrix was rotated according to varimax method.

Results and Discussion

Between some of the investigated compounds in the spruce needes as well as in the humus layer of the investigated background forest sites significant positive correlations have been identified (a selection of the more pronounced ones is given in figures 1 and 2). This clearly indicates that even in backgound areas higher loads include several semivolatile compounds. Since not even the toxic impact of one compound is totally understood at ecosystem level, the combined action of several compounds (e.g. synergisms) is not clear at all.

The compounds in the humus layer - indicating total input over several years (dry and wet deposition, litterfall) – showed more often and more pronounced significant correlations than the contents of the spruce needles (as an indicator for the atmospheric load during exposed growing period). Showing a higher causal interrelationship, these compounds often show significant correlations. For instance, lower chlorinated furans (TCDF, PeCDF) in the needles correlate significantly with the sum of PAH in the needles, whereas the sum of polychlorinated dibenzodioxins and –furans (PCDD/F) does not correlate (figure 1). Similar to this result the sum of polychlorinated dibenzofurans (PCDF) in the needles significantly correlates with lead in the needles, whereas PCDD/F does not correlate (figure 1). These results are plausible because higher shares of lower chlorinated PCDD/F or PCDF in homologue profiles have been observed at sites located closer to emission sources [9-13]. Therefore, higher shares of lower chlorinated PCDD/F homologues or PCDF are seen as an indication of an influence of less distant sources [14]. As a consequence, the sum of PAH or lead in the needles of these background sites is higher, too. The concentrations of the pesticides HCB and HCH in the needles showed a significant positive correlation, too (figure 1), whereas in particular HCH in the needles do not correlate with compounds emitted without being associated with a particular use.

Pronouncedly significant positive correlations have been identified between nearly all semivolatile organic compounds in the humus layer (figure 2). The PCDD/F concentration in the humus layer of the investigated background sites can be sufficiently described by the sum of PCB in this compartment (R^2=0.75, equation 1).

$$\log cO_{PCDD/F} = 2.048 + 0.148 * cO_{PCB} \qquad (1)$$

$cO_{PCDD/F}$.............. PCDD/F concentration in the humus layer in ng/kg
cO_{PCB}.................. PCB concentration in the humus layer in µg/kg (sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180)

The correlations between less chlorinated PCDD/F homologues and PCB are more pronounced than those between octachlordibenzodioxin and PCB. Furthermore, pronounced positive correlations occurred between PCDD/F and PAH, PCB and HCB, HCB and DDX (figure 2). It is remarkable that HCH correlate with HCB and DDX, but not with PCDD/F and PAH.

This result, together with the needle results, shows that the difference of the load of the investigated background sites seems to be characterised by two types of emission. One type represents compounds that are definitely emitted by their use (e.g. as pesticides), and the other type represents compounds that are emitted without being associated with any specific purpose. This has been further confirmed by the results of a principal component analysis for the humus layer. The complete data structure (PCDD/F, PCB, HCH, HCB, DDX, PAH, Pb) can be described by two principal components, the first explaining 61 % and the second 20 % of total variance of the data. The first component has high loadings for PCDD/F, PAH and Pb, which represent substances emitted without being associated with any specific purpose. The second principal component has high loadings for HCH, DDX and HCB – compounds used as pesticides (figure 3). It is remarkable that HCB as well as PCB represent substances with loadings higher than 0.5 for both principal components. This might be related to the fact that HCB and PCB are not only emitted by their specific use, but by various other sources, too.

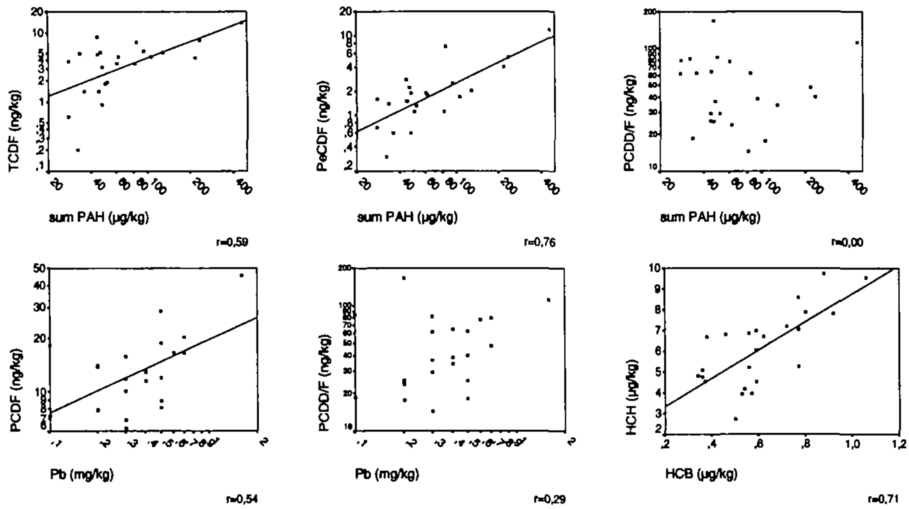

Figure 1: Correlations between semivolatile organic compounds and lead in the spruce needles (1st needle age class taken in October)

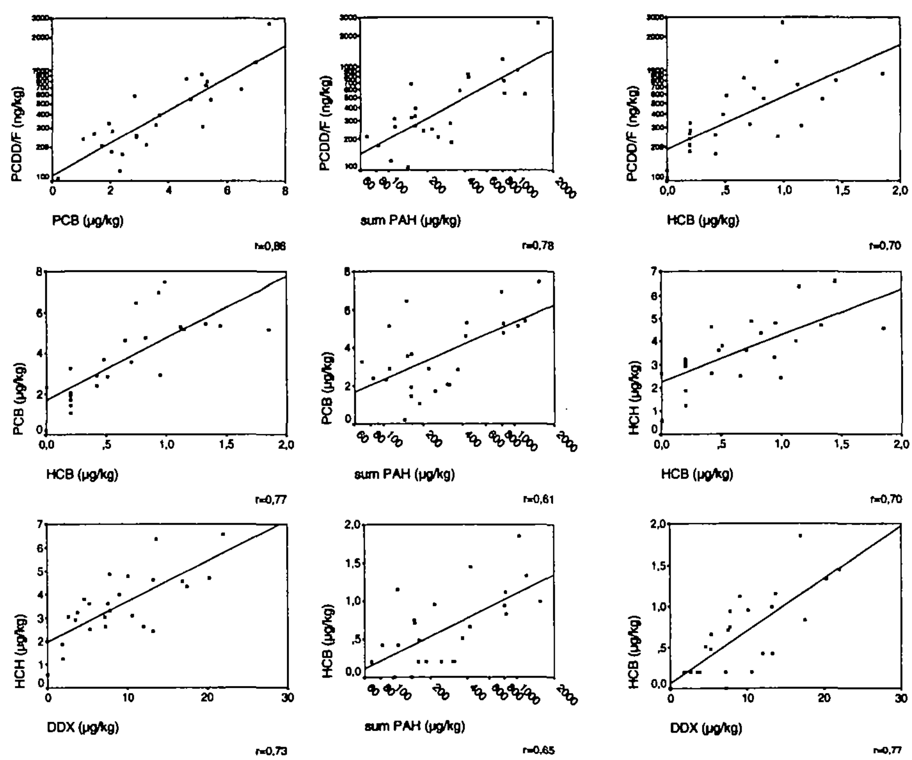

Figure 2: Correlations between semivolatile organic compounds in the humus layer

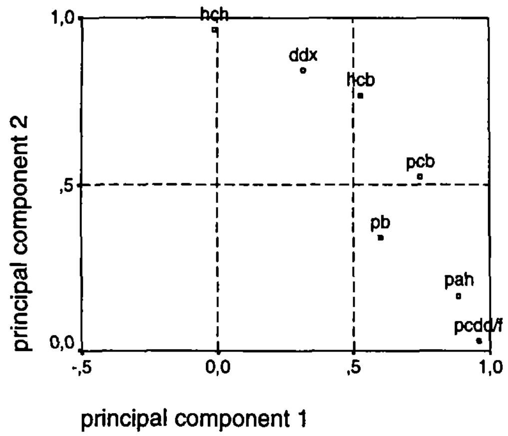

Figure 3: Varimax-rotated factor loading plot for principal component 1 and 2

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