Time Trends of HCHs and HCB in Muscle of Reindeer (*Rangifer tarandus*) from Lapland, Northern Sweden, 1983-1995

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Introduction

The long-term monitoring of bioaccumulating contaminants in biota from Swedish environments is based on analysis of matrices collected in locally uncontaminated, pristine areas throughout the Swedish mainland (1,2). In the north-western, subarctic region, reindeer (*Rangifer tarandus*) tissues are selected as representative matrices for monitoring of airborne contaminants, primarily due to its simple herbivorous food chain. *The Arctic Monitoring and Assessment Programme (AMAP)* recommends collection of baseline data for heavy metals, OCs and radionuclides in caribou/reindeer in the Arctic environment to be mandatory for participating states (3).

Material and Methods

Sample collection: Since the early 1980s, collection of leg muscle, liver, kidney, suet, and left under jaw with teeth (for age determination) from at least 50 male reindeer has been carried out annually at regular slaughtering in September. Most animals were three years old. Sampling, transport and preparation of specimen follows standard protocols (4). Sampling has been carried out in three districts along the Swedish mountain chain. The present paper reports on data of reindeer collected in Gabna, Lævas and Girjas Saami Villages in northern Lapland. The district reaches from the Swedish/Norwegian border eastwards to the central forest area. The reindeer spend the summer in the westernmost part of the high mountain area. Summer diets include grasses, sedges, twigs, leaves, lichens and mushrooms. During autumn they migrate eastwards to winter grounds in the central coniferous forest areas of northern Sweden, where they primarily feed on lichens, noted for their ability to accumulate nutrients and contaminants from the air. Winter diets also include sedges and twigs.

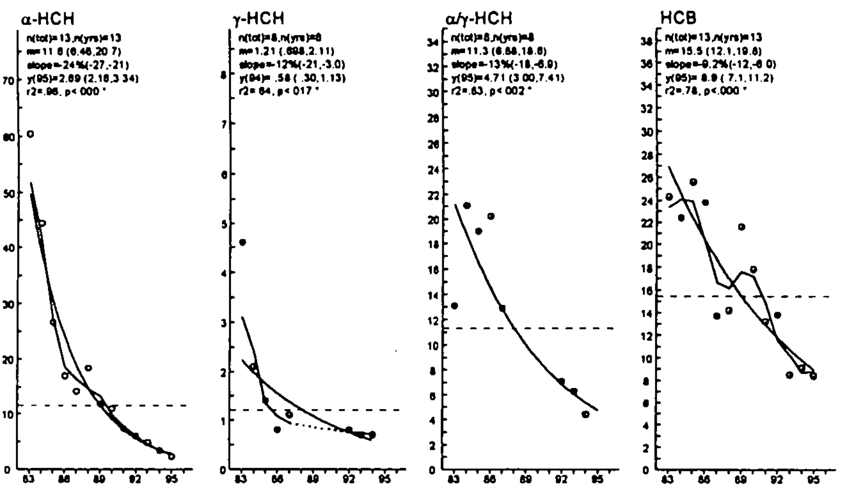
Sample preparation: Ten males, three years old were selected for chemical analyses. A pooled sample based on aliquots of leg muscle from each individual was prepared for each year of the series.

Chemical analyses: High Resolution Gas Chromatography (HRGC) with capillary columns was used for determination of HCB (hexachlorobenzene) and (hexachlorocyclo-hexanes; α-HCH, β-HCH, and γ-HCH). The analytical procedures including extraction and determination of lipid concentration are described elsewhere (5). All analytical results are expressed in ppb on a lipid weight basis. Data of ΣDDT and PCB are not discussed since concentrations are close to or below detection limits. Missing values for γ-HCH, 1988-91 are due to analytical error and will be completed later.

Statistical analysis: Simple log-linear regression analysis based on the annual concentrations in the pooled samples has been carried out in order to detect time trends.

Results and Discussion
The analytical results are presented in the Figure below, which also includes results of statistical analyses. The concentrations of α-HCH, γ-HCH and HCB decrease significantly over time for the whole study period. The average annual decrease of α-HCH is 24% (r^2 = 0.96, p<0.001), for γ-HCH 12% (r^2 = 0.64, p<0.05) and for HCB 9.2% (r^2 = 0.78, p<0.001).

α-HCH, γ-HCH, α/γ-HCH, HCB, ppb lipid weight, reindeer muscle



Technical grade hexachlorocyclohexanes (HCH) consists of 65-70% α-HCH, 7-10% β-HCH, 14-15% γ-HCH and approximately 10% of other isomers and diverse compounds. *Technical lindane* contains more than 90% of γ-HCH, the substance with insecticidal effect (6). Lindane, (γ-HCH) is one of the most widely used organochlorine insecticides for agricultural purpose. It has been used as a broad spectrum insecticide since the early 1950s for purposes that also include treatment of seeds and soil, trees, timber and stored materials; treatment of animals against ectoparasites and in public health. Lindane undergoes rapid degradation in the presence of ultraviolet irradiation, and in field conditions, under humid or submerged conditions, its half-life varies from a few days to three years depending on the type of soil, climate and other factors (7). Although most developed countries have prohibited the use of technical grade HCH, it is still widely used elsewhere on a large scale, e.g. in India (8), but also in North America, and Europe (France and Italy). The annual use in India and China in 1980 accounted for more than 84% of the total technical HCH consumption in the world. The use of both α-HCH and γ-HCH decreased dramatically between 1980 and 1990 (9). The total global usage of technical HCH was estimated to be 40 000 t for 1980 and 29 000 t for 1990. The total global usage of technical lindane was 5900 t for 1980 and 4000 t for 1990 (9).

Hexachlorobenzene (HCB) was earlier used as fungicide and flame retardant. It is used as source to produce pentachlorophenol and occurs as a contaminant in that product and other. HCB is a by-product also in the production of chlorine gas and chlorinated compounds, including several pesticides. Combustion of PVC is a potential source for formation of HCB (10).

Temporal trends of α-HCH, γ-HCH and HCB in the subarctic region, presented in this paper, show a continued decline during the 1980s and the early 1990s. Corresponding declines in freshwater matrices from northern Sweden are also shown elsewhere (11,12). The annual decline of α-HCH in Arctic char from Lake Abiskojaure, northern Lapland, and in pike from Lake Storvindeln, southern Lapland, was 18% and 9.6%, respectively. Corresponding figures for the HCB decline were 6.0% and 5.8%, respectively. In general, only small differences in declining rates between terrestrial and aquatic environments and no obvious differences between southern locations and northern areas were found. Nor could any convincing difference in concentrations of HCHs be revealed between north and south that could indicate increasing concentrations to the north (11,12). As shown in the Figure, the ratio α-HCH/γ-HCH in reindeer declines over time from above 21 in 1984 to approximately 4 at the end of the period. The annual decline is 13% ($r^2 = 0.83$, $p<0.01$). Decreasing ratios in almost all investigated time series from Swedish freshwater and marine environments around Sweden were also reported (12), although they were lower in aquatic organisms compared to those in reindeer. Levels of α-HCH in reindeer and Arctic char from Lake Abiskojaure (12) were of the same magnitude in both the start and the end of the period, while levels of γ-HCH were considerably lower in reindeer than in char. The decreasing levels and declining α-HCH/γ-HCH ratios found in both aquatic and terrestrial matrices in the Baltic and Fennoscandia are most likely explained as an effect of the decreased production and use of pesticides in the former Soviet Union following drastic changes within the economic system recently reported (13, 14). Part of the decline may also depend on the national/international drop in use of HCHs and the replacement of technical HCH by γ-HCH after the 1970s (9).

HCB, followed by HCH isomers, seems to be the most abundant organochlorine for terrestrial mammals in the Canadian North (15,16). The concentrations of these compounds were similar among species and areas, *e.g.* levels in liver of herbivores were 0.4-6.9 ppb (wet weight). HCB and HCHs are also the major OC contaminants found in tissues of reindeer/caribou in the Arctic circumpolar area (15,16). That reflects the predominance of these contaminants in atmospheric deposition to the reindeer grazing areas (17).

The concentrations of α-HCH and HCB in reindeer from northern Sweden are of the same magnitude as levels in reindeer from Svalbard, where few local sources of contamination are present. The mean level of HCH was approximately 4.7 ppb (lipid weight) in fat of female reindeer from Svalbard and 1.7 ppb (lipid weight) in males. HCB mean levels in fat were approximately 9.4 in females and 11 ppb (lipid weight) in males. The mean levels in liver, on a lipid weight basis, were of the same magnitude (18). According to data assessed in AMAP, levels of *e.g.* HCH in reindeer/caribou liver across the Arctic appear to be fairly uniform (17). However, analyses of HCB and ΣHCH in fat of caribou from five sites in the Northwest Territories of Canada collected in 1991-92 reveal somewhat higher levels than found in reindeer in Svalbard and northern Sweden. The highest mean levels were found in Cape Dorset and Lake Harbour herds and the lowest in the Bathurst herd. HCB levels in fat tissue ranged approximately between 33 and 129 ppb (lipid weight) and ΣHCH levels approximately between 10 and 40 ppb (lipid weight), most of it was α-HCH (16).

The Arctic is in focus for major atmospheric pathways which result in long-range transport of contaminants into and within the Arctic. The contaminants are widely but not uniformly, distributed around the Arctic (17). Different patterns are shown for different substances, which might reflect a different origin or different deposition mechanisms.

The reindeer/caribou seems to be a most relevant species for monitoring of the studied bioaccumulating substances, deposited to the grazing areas in the Arctic and subarctic regions. Levels of some OCs appear to be fairly uniform across the Arctic.

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