PERSISTENT ORGANIC POLLUTANTS IN THE FINNISH AND RUSSIAN SEMI-DOMESTICATED REINDEER (*RANGIFER TARANDUS TARANDUS* L.)

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Introduction

Polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) are widely dispersed persistent organic pollutants (POPs) having indissoluble and lipophilic nature. This makes them pose a threat to animals and humans when entering the food web[1, 2]. The distribution of POPs in animal body has been studied in different animal species. There have been variations in the concentrations of POPs in different tissues. In Danish study liver, leaf fat, flank and shank of sheep were analyzed. The highest PCDD/Fs were observed to be in sheep liver[3]. Furthermore, PCDD/Fs have been noticed to be 8 to 27 times higher in liver of sheep than its muscle tissue. Similar phenomenon had not seen with the studied cows[4]. In the study of pigs it was found that liver was again the main collector of organic pollutants when comparing the dioxin-like compounds in liver, lung, kidney, subcutaneous fat, mesentery and muscle. However, PBDEs have not been observed to accumulate in liver as similar manner[5]. In Norwegian study POPs were analyzed from muscle, liver, tallow and bone marrow of semi-domesticated reindeer (*Rangifer tarandus tarandus* L.). It was found that PCB levels were lower in muscle than in liver[6]. The property of liver to accumulate toxicants appears also in the study of lamb organs; liver had clearly higher PCDD/Fs than kidneys and heart[7]. In this study different organs of Finnish and Russian semi-domesticated reindeer were analyzed for PCDD/Fs, PCBs and PBDEs to figure out how contaminants are distributed in the reindeer body. Reindeer liver PCDD/F and DL-PCB concentrations were compared between adult reindeer and reindeer calves from Finnish Lapland and Kola Peninsula in Russia.

Materials and methods

The reindeer tissue samples were gathered from one adult female (age about 10 years) and one male calf (age about 6 months) from southern reindeer herding area in Finland in 2008. In addition, blood and udder samples were gathered from two adult female reindeer (age about 10 years) from northern reindeer herding area in Finland in 2010. The Finnish reindeer liver samples were sampled in the northern (calves n=5, adult n=5), middle (calves n=3, adult n=2) and southern (calves n=3, adult n=1) Lapland in 2006 and 2010. The Russian reindeer liver (n=7), muscle (n=4) and kidney (n=3) samples were gathered from adult reindeer in Lovozero district in Murmansk area, Kola Peninsula in 2013.

The tissues were cut using clean instruments and placed in polyethylene bags. The samples were preserved at -20°C until the analysis was accomplished. The chemical analyses were carried out at the Chemical Exposure Unit of the National Institute for Health and Welfare. The laboratory has been accredited according to the EN ISO/IEC 17025 standard by FINAS. The scope of accreditation includes PCDD/F, PCB and PBDE analyses from biological matrices. The Russian samples were analyzed with Waters Autospec system in the Russian State Center for Quality and Standardization of Veterinary Drugs and Feed (VGNKI). The institution is certified by RF Standardization, Metrology and Certification Committee (Gostandart) as the Veterinary Drugs and Feed certification and testing center.

After homogenization, the solid tissue samples were freeze-dried and fat was extracted with ethanol-toluene mixture using ASE 300 apparatus. The solvent was exchanged to hexane and the fat percentage was determined

gravimetrically. The samples were defatted on an acidic multilayer silica column, purified and finally fractionated on alumina and activated carbon columns. The studied compounds (17 toxic PCDD/Fs, 12 DL-PCBs and 15 PBDEs) were analyzed with HRGC/HRMS method, using a selected ion monitoring mode (SIM) with a resolution of 10,000. Further details of the analytical method can be found elsewhere[8].

Results and discussion:
Finnish reindeer organ samples

The fat based WHO-PCDD/F-TEQ and WHO-PCB-TEQ concentrations (lowerbound results) and sum PBDE concentrations are shown in Figure 1.

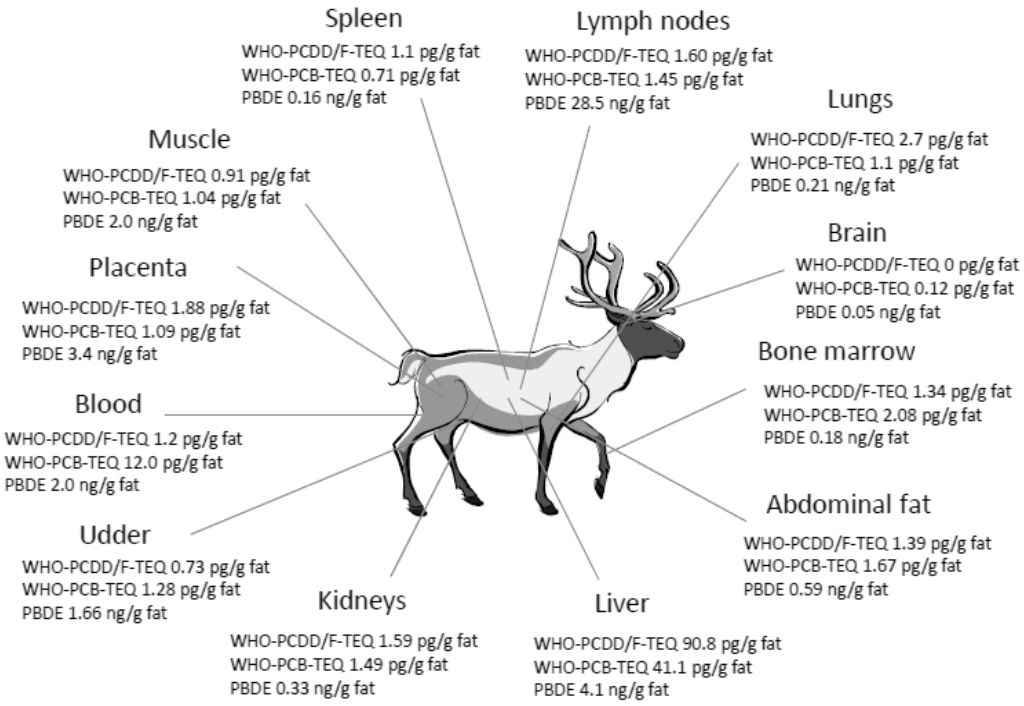

Figure 1. WHO-PCDD/F- and WHO-PCB-TEQs along with the sum of PBDEs are shown in different organs of reindeer in Finland.

It is seen that the concentrations of WHO-PCDD/F- and WHO-PCB-TEQs were quite equal in the studied organs. However, the liver is an exception, because it accumulates clearly more dioxin-like compounds than other organs. It may be the detoxification properties of liver, which makes it to gather toxic compounds in greater extent than the other internal organs. This assumption is supported by the earlier findings of POP accumulation in Finnish reindeer liver[9].

PBDE sum concentrations were generally similar, and low, between the studied organs; concentration being slightly higher in liver and placenta than in other organs. The lymph node samples were, however, an exception, because they had clearly higher PBDE sum than any of studied samples, for e.g. 7 times that of liver. It is possible that PBDEs are transported from gastrointestinal tract via lymphatic fluid straight to the accumulating sites, i.e. the lymph nodes. It is interesting, when we are speaking of lipophilic compounds and it could be more probable that they will accumulate to more fatty tissues, for e.g. in abdominal fat. That is not the case, however, and there may be some unique accumulating manners of PBDEs in animal body. It is not known if PBDEs interfere the functions of lymph nodes in immunological processes, but that may be physiologically possible.

Russian reindeer organ samples
PCDD/F- and DL-PCB concentrations (as fat based WHO-TEQs) in Russian reindeer organ samples are shown in Table 1.

Table 1. WHO-PCDD/F-TEQs and WHO-PCB-TEQs (pg/g fat) in Russian reindeer organ samples (mean values).

Sample	WHO-PCDD/F-TEQ	WHO-PCB-TEQ
Reindeer muscle (n=4)	0,92	3,62
Reindeer kidneys (n=3)	2,03	9,2
Reindeer liver (n=4)	62,13	140,15

It is seen that dioxins in muscle samples are below the limits (3 pg/g fat in Russia, 2.5 pg/g fat in EU), but total WHO-PCDD/F-PCB-TEQs are over the EU limit (4 pg/g fat). PCDD/Fs and PCBs are roughly two times higher in kidneys than in muscle (no regulation exists for kidneys). Dioxins in liver are higher by an order of magnitude than the current Russian limits (6 pg/g fat).

It can be noted that PCDD/F levels in Russian muscle, kidney and liver samples are close to Finnish, but DL-PCB concentrations in all tissues from Russia are several-fold higher than in tissues from Finland. The main contributor to overall toxicity in Russian samples was PCB-126, a compound demonstrating clear bioaccumulation potential[10]. PCB-118 and -105 were basic contributors to overall DL-PCB concentration. Stable pattern of high PCB-126, -118 and -105 concentrations in all Russian samples may point at a common intensive PCB contamination source located on the territory of Kola Peninsula.

Reindeer liver samples
PCDD/F- and DL-PCB concentrations (as fat based WHO-TEQs) in Finnish and Russian reindeer liver samples are shown in Figure 2.

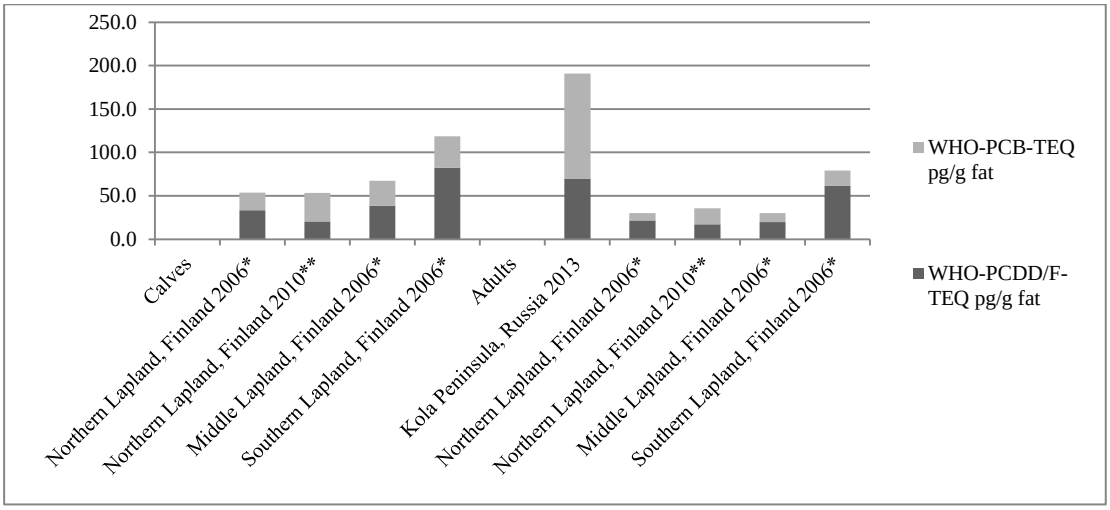

Figure 2. WHO-PCDD/F- and WHO-PCB-TEQs in reindeer liver samples from Finnish Lapland and Kola Peninsula in Russia. *[10], **[11].

It is seen that in Finnish Lapland reindeer calves had higher WHO-PCDD/F- and WHO-PCB-TEQs than adult reindeer. The common trend in Finnish reindeer is that contaminant concentrations increase from northern to southern areas. However, the highest total TEQ level is observed in adult reindeer liver from Kola district, which is high in the north. It seems that in Kola Peninsula there may be the local pollution sources which affect to the

contaminant concentrations seen in reindeer liver. In addition, WHO-PCDD/F-TEQs were quite equal in Russian adult reindeer liver samples and southern Lapland calf samples from Finland in 2006. That could mean there is also some local contamination source of PCDD/Fs in southern Lapland, too. It is generally seen in the Finnish samples that liver accumulates more PCDD/Fs than DL-PCBs. However, in the calf and adult reindeer samples from northern Lapland in 2010 had more DL-PCBs than PCDD/Fs of total TEQs. Also adult reindeer samples from Kola district had relatively big contribution of DL-PCBs. That may indicate the contamination source near the border area of northern Finland and Russia in more recent years, while the samples of these areas had been collected in 2010-2013. The reindeer samples from northern Lapland in 2006 had smaller contribution of DL-PCBs of total TEQ than samples gathered in 2010. There could be varying exposure conditions between the years.

It was concluded that WHO-PCDD/F- and WHO-PCB-TEQ concentrations were generally quite similar in internal organs of Finnish reindeer. However, liver is an exception when it accumulates dioxin-like compounds much more effectively than other organs. That may be due to specific functions of liver in detoxification processes. PBDE compounds were generally equal in reindeer organs, but showed clearly higher level in lymph nodes. That may be due to mechanism of PBDEs transported via lymphatic fluid.

Reindeer liver samples showed varying concentrations of PCDD/Fs and PCBs. Finnish reindeer calves had higher contaminant levels than adult reindeer, but adult reindeer from Kola Peninsula showed to have the highest concentration of total TEQ (about 190 pg/g fat). The EU maximum level for terrestrial animal, where bovine belongs, liver is 10 pg/g fat WHO-PCDD/F-PCB-TEQ[12], so the limit is exceeded not only the Russian samples but also in all of the Finnish samples. The situation with reindeer liver looks quite similar to the previously described anomaly with sheep liver, which led to changes in the EU regulation. The current results suggest that, similarly, reindeer liver should be treated separately from livers of other terrestrial animals, and possibly should be reported on a wet weight basis (like sheep liver according to new EU rules). EU limit for WHO-PCDD/F-TEQ in sheep liver is 1.25 pg/g wet weight. In our results of reindeer liver, PCDD/Fs (as WHO-TEQs) are at 1.0-1.5 pg/g wet weight.

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