Area	Muscle	Liver	Kindey
		Hg	
Kola Peninsula, n=6	0.0018 (0.0010-0.0033)	0.016 (0.012-0.021)	0.062 (0.056-0.068)
Pechora basin, n=6	0.0035 (0.0024-0.051)	0.035 (0.019-0.033)	0.096 (0.075-0.12)
Taymir, west, n=5	0.0015 (0.0006-0.0036)	0.012 (0.011-0.015)	0.058 (0.039-0.086)
Taymir, east, n=4	—	0.0089 (0.0054-0.015)	0.033 (0.018-0.062)
Chukotka, coast, n=2	—	0.020 (0.008-0.051)	0.11 (0.047-0.23)
		Pb	
Kola Peninsula, n=6	0.013 (0.009-0.021)	0.071 (0.060-0.083)	0.057 (0.045-0.070)
Pechora basin, n=6	0.021 (0.018-0.026)	0.088 (0.062-0.12)	0.076 (0.059-0.098)
Taymir, west, n=5	0.017 (0.013-0.021)	0.056 (0.033-0.093)	0.048 (0.030-0.079)
Taymir, east, n=4	0.0052 (0.0029-0.010)	0.034 (0.021-0.051)	0.034 (0.019-0.060)
Chukotka, coast, n=2	0.0059 (0.0033-0.011)	0.095 (0.054-0.017)	0.067 (0.044-0.10)
		Cd	
Kola Peninsula, n=6	0.011 (0.0073-0.015)	0.13 (0.12-0.15)	0.40 (0.28-0.56)
Pechora basin, n=6	0.019 (0.015-0.023)	0.16 (0.14-0.18)	0.52 (0.37-0.73)
Taymir, west, n=5	0.011 (0.0078-0.016)	0.093 (0.050-0.17)	0.28 (0.18-0.043)
Taymir, east, n=4	0.0043 (0.0022-0.0083)	0.081 (0.043-0.015)	0.24 (0.14-0.42)
Chukotka, coast, n=2	0.014 (0.0083-0.024)	0.20 (0.14-0.28)	0.43 (0.22-0.82)

Table 5.12. Geometric means and 95% confidence interval of effective rates of accumulation of heavy metals in reindeer tissues (μg/g ww per year).

tionship are given in Table 5.12, and these can be considered as the effective rates of accumulation of metals in reindeer tissues. The lowest values normally occur in the Taymir Peninsula, however, the values do not differ by more than a factor of 3 and the differences are therefore of no great significance.

Concentrations of Cd and Hg in muscle tissue sampled in 2001 are very close to those found in 1994/1995 in the Russian North (AMAP, 1998), while levels of Pb in muscle are an order of magnitude lower than those reported earlier. In comparison with 1995 values, liver/muscle concentration ratios calculated in 2001 are significantly higher for all HMs, and are similar to those measured in other regions of the Arctic (AMAP, 1998). Levels of all HMs are similar to, or slightly lower than those determined in the Canadian Arctic in 1998-2001 (CACAR, 2003). However, as concentrations of HM in Canadian reindeer are reported on a dry weight basis, direct comparison is not possible; on a dry wt basis, absolute values are typically up to an order of magnitude greater.

5.3.3. PTS in the Arctic hare

Tissues of Arctic hare (*Lepidus timidus*) were sampled at all sites, except for coastal Chukotka. The number of single samples of each tissue, collected at a given site and used in the preparation of pooled samples, ranged from 4 to 10 (see Table 5.1). Equal numbers of male and female animals, all younger than 3 years, were sampled at each site. The muscle, liver and kidney of hare were analyzed for all PTS listed in Section 1.2.4.

PTS concentration relationships with hare sex and tissue type

(a) Organochlorines

Only a few OCs (HCB, *p,p'*-DDT, *p,p'*-DDE, PCB-118, PCB-138 and PCB-153) were detectable at all sites and in the majority of samples. No significant concentration relationship to either sex or tissue type was identified for these OCs in hare.

(b) Heavy metals

HMs occur in detectable concentrations in all samples, except for Hg in muscle tissue. Calculated male/female concentration ratios for Hg, Pb, and Cd do not differ significantly from unity and are neither site nor tissue specific. Mean concentrations for HMs were, therefore, calculated using data for both sexes. The distribution of the three HMs between tissues is similar for both sexes, and approximates that found in reindeer. Relative levels of contaminants in muscle, liver and kidney are in the ratio of 1:11:5 for Pb and 1:26:160 for Cd (based on geometric means of ratios for pooled samples).

Levels and trends

(a) Organochlorines

The levels of OCs that were generally above detection limits in tissues of hare (HCB, *p,p'*-DDT, *p,p'*-DDE, PCB-118 and PCB-153) did not follow any geographical trend. Geometric means of OC concentrations range from 0.06 ng/g ww (*p,p'*-DDT, *p,p'*-DDE) to 0.12 ng/g ww (HCB). Concentrations of PCB-138, PCB-180, as well as α- and γ- HCH occur at similar levels at several sites. In a few samples, some of the other OCs (PCBs, Mirex, and cyclodienes) were found in concentrations close to the detection limit. Concentrations of all detectable OCs in hare tissues are 2-4 times lower than those in reindeer, and are far below the limit values for these substances established in Russia.

Area	pg WHO-TEQ/g ww	pg WHO-TEQ/g lipids	pg WHO-TEQ/pg*
	Muscle		
Kola Peninsula	0.60	29	0.18
Pechora basin	0.043	2.7	0.15
Taymir, west	0.034	1.4	0.084
Taymir, east	0.041	3.5	0.18
Chukotka, inland	0.037	1.8	0.14
	Liver		
Chukotka, inland	0.10	2.5	0.082

Table 5.13. Concentrations (expressed as TEQ) of PCDD/Fs in hares in the Russian Arctic in 2001.
* – ratio of PCDD/F concentration in pg WHO-TEQ/g to that in pg/g

(b) PCDD/Fs

Concentrations of 2,3,7,8-substituted PCDD/Fs were analyzed in pooled samples of hare tissues collected at each site. Results are presented in Table 5.13 and Figure 5.12. PCDDFs in hare tissues follow the same spatioal distribution pattern as for reindeer. All concentrations are at levels below the (maximum) permissible level for meat.

(c) PAH

Hare tissues were analyzed for the same PAH set as were reindeer tissues. In contrast to OCs, most PAH concentration levels in hare are either comparable with those in reindeer or are higher. Only phenanthrene concentrations in hare muscle are, for most sites, found to be several time lower than those in reindeer.

(d) Brominated flame-retardants

Samples of hare tissue were analysed for 2,2',4,4'-tetrabromodiphenyl, 2,2',4,4',5-pentabromodiphenyl, 2,2',4,4'-tetrabromodiphenyl ether and 2,2',4,4',5-pentabromodiphenyl ether. In all samples, concentrations of these substances were below the detection limit of 0.2 ng/g ww.

(e) Heavy metals

HM concentrations measured in hare tissues are given in Table 5.14. Concentrations are usually several times lower than those found in reindeer, with the exception of Cd in kidney tissue, for which levels in hare and reindeer are comparable. Spatial distribution patterns observed for all three HMs are similar to those for reindeer. The lowest concentrations occur in Chukotka and eastern Taymir. Concentrations of HMs in hare tissues measured in this study are similar to those reported for hares in Finland in 1995 (AMAP, 1998). Differences in levels between the data from Finland in 1995 and Russia in 2001 are relatively small (within a factor of two), with the exception of Pb in muscle, which is 4.4 times higher in the Russian North.

5.3.4. PTS in birds

Waterfowl and terrestrial game birds harvested by indigenous peoples in the Russian Arctic for the project, were analyzed for all contaminants listed in Section 1.2.4. Samples tissues of the following groups of birds were collected:

- Grazers (geese that graze mainly on aquatic and terrestrial vegetation): bean goose (*Anser fabalis*), white-fronted goose (*Anser albifrons*), goldeneye duck (*Bucephala clangula*) and ptarmigan (*Lagopus sp.*);
- Omnivores (surface-feeding ducks with a varied diet consisting mainly of aquatic vegetation): pintail (*Anas acuta*), wigeon (*Anas penelope*), and teal (*Anas crecca*);
- Molluscivores (diving ducks feeding mainly on invertebrates): eider (*Somateria mollissima*), and long-tailed duck or oldsquaw (*Clangula hyemalis*);
- Piscivores (diving ducks feeding mainly on fish): scaup (*Aythya marila*), merganser (*Mergus sp.*), scoter (*Melanitta sp*).

For most sites, equal numbers of male and female birds of each groupwere harvested. Exceptions were: omnivores (1 male pintail) and piscivores (1 female scoter) in eastern Taymir; grazers (1 female goose) at inland Chukotka; and molluscivores (1 male eider) at coastal Chukotka.

PTS concentration relationships with bird sex

No significant concentration dependence on sex was identified for any of the detectable OCs, for Hg and Cd in all bird groups, and for Pb in waterfowl. Pb concentrations in the muscle tissue of male browsers were consistently about twice as high as those measured in females at all six sites; the male/female ratios ranging from 1.7 to 2.6, with a geometric mean of 2.1 for the six values. Since the male/female ratios for Pb in browsers are not particularly high, the ratio is independent of site, and the same sample pattern for sexes was followed at all sites (50% male and 50% female), all geometric means, including those for Pb concentrations in browsers, were calculated using data for both sexes

Levels and trends

(a) Organochlorines

Concentrations of OCs in birds are shown in Tables 5.15a and 5.15b and Figures 5.14 and 5.15. The lowest contamination levels are found in the muscle tissue of browsers. The only OC that was repeatedly detected in these birds was *p,p'*-DDE. Levels of ΣPCB_{15} in browsers

Table 5.14.
Concentrations (mean and standard deviation; µg/g ww, n=2) of HMs in tissues of the Arctic hare (< 3 years of age) in the Russian Arctic in 2001.
[a] The range (in brackets) is given where the standard deviation is larger than 50% of the mean.

Tissue	Area	Hg	Pb	Cd
Muscle	Kola Peninsula	<0.001	0.005 (<0.001–0.008)[a]	0.010±0.002
	Pechora basin	<0.001	0.012±0.001	0.016±0.004
	Taymir, west	<0.001	0.012±0.004	0.014±0.003
	Taymir, east	<0.001	0.022 (<0.001-0.042)[a]	0.007±0.001
	Chukotka, inland	<0.001	0.031 (<0.001-0.059)[a]	0.007±0.001
Liver	Kola Peninsula	0.007 (0.002-0.017)[a]	0.12±0.02	0.29±0.11
	Pechora basin	0.020±0.002	0.19±0.03	0.36 (0.20-0.52)[a]
	Taymir, west	0.021±0.002	0.18±0.04	0.40±0.11
	Taymir, east	0.010±0.004	0.10±0.03	0.19±0.06
	Chukotka, inland	0.020±0.006	0.087±0.013	0.21±0.06
Kindey	Kola Peninsula	0.066±0.008	0.048±0.013	2.0±0.9
	Pechora basin	0.11±0.02	0.072±0.023	2.5±1.1
	Taymir, west	0.098±0.021	0.078±0.022	2.2±0.9
	Taymir, east	0.053±0.008	0.038±0.008	1.0±0.3
	Chukotka, inland	0.051±0.004	0.045±0.019	1.04±0.08

Bird group	Area	ΣPCB15	HCB	ΣHCH	ΣCHLOR
Browsers	Kola Peninsula, n=2	1.52 (1.49-1.56)	0.10 (0.05-0.20)	0-0.46[a]	0-0.21[a]
	Pechora basin, n=2	0.6-2.0[a]	<0.05	<0.20	<0.20
	Taymir, west, n=2	0.6-1.1[b]	<0.05-0.20	0.07-0.41[a]	<0.20
	Taymir, east, n=2	0.6-1.1[b]	<0.05-0.14	0.19 (0.14-0.27)	0-0.21[a]
	Chukotka, inland, n=2	1.46 (1.20-1.77)	<0.05-0.35	<0.20	0-0.24[a]
	Chukotka, coast, n=2	0.6-1.1[b]	<0.05-0.34	0.10-0.23[a]	<0.20
Grazers	Taymir, west, n=2	2.81 (2.07-3.82)	0.06 (0.05-0.08)	0.18-0.28[a]	<0.20
	Taymir, east, n=2	2.87 (2.58-3.21)	0.10 (0.07-0.15)	0.12-0. 28[a]	<0.20
	Chukotka, inland, n=1	1.14	0.17	<0.20	<0.20
Omnivores	Pechora basin, n=4	2.30 (1.62-3.34)	0.16 (0.07-0.37)	0-0.89[a]	0-0.57[a]
	Taymir, west, n=3	2.88 (2.32-3.45)	0.22 (0.13-0.36)	0-0.43[a]	0.08-0.39[a]
	Taymir, east, n=2	3.44 (2.54-4.66)	0.36 (0.17-0.76)	0.50 (0.26 - 0.97)	0.16 (0.11-0.23)
	Chukotka, inland, n=3	3.20 (2.23-4.47)	0.28 (0.15-0.54)	0.41 (0.24-0.76)	0.10-0.50
Molluscivores	Kola Peninsula, n=2	3.88 (2.57 –5.86)	0.39 (0.25-0.62)	0.52 (0.39 –0.71)	0.33 (0.28-0.40)
	Taymir, east, n=2	13.6 (10.7-17.2)	1.36 (1.22-1.50)	2.21 (1.78-2.64)	2.67 (2.01-3.55)
	Chukotka, inland, n=2	4.09 (3.32-5.04)	0.43 (0.29-0.56)	1.71 (1.28-2.13)	0.64 (0.52-1.00)
	Chukotka, coast, n=3	3.47 (2.81-4.01)	0.32 (0.15-0.36)	0.60 (0.40-0.80)[b]	0.47 (0.37-0.61)[b]
Piscivores	Kola Peninsula, n=2	4.07 (3.63-4.65)	0.42 (0.32-0.55)	<0.20	0-0.21[a]
	Taymir, east, n=1	3.88	0.12	0.32	0.31
	Chukotka, inland, n=2	1.71 (1.68-1.74)	0.23 (0.18-0.30)	<0.20	<0.20

Table 5.15a. Concentrations (geometric mean and range; ng/g ww) of OCs in the muscle of birds in the Russian Arctic in 2001.
a In at least one sample, more than half of the concentrations were below the detection limit. Concentrations below the detection limit were set to zero or to the detection limit when determining lower and upper limits of concentration ranges.
b The range is given only for oldsquaw (n=2). Concentrations in eider were below the detection limit.

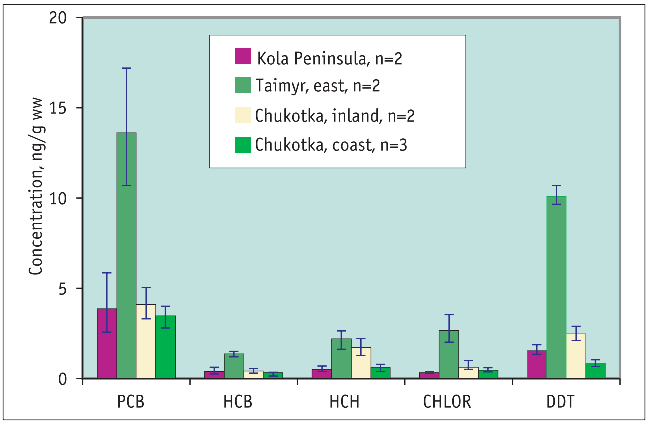

Figure 5.14. Geometric means and ranges of OC concentrations in molluscivores. PCB=ΣPCB15, HCH=ΣHCH, CHLOR=ΣCHLOR, and DDT=ΣDDT.

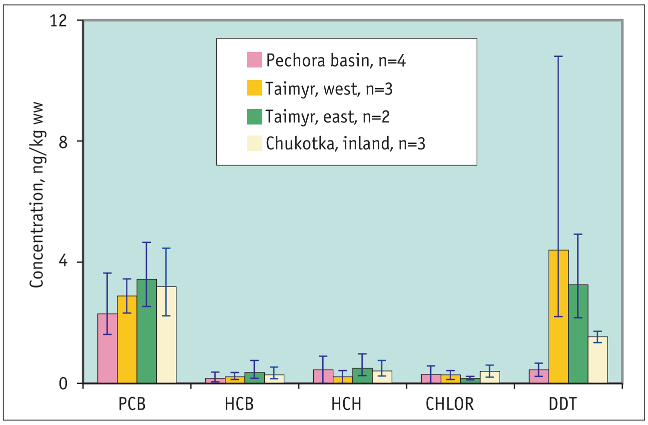

Figure 5.15. Geometric means and ranges of OC concentrations in omnivores. PCB=ΣPCB15, HCH=ΣHCH, CHLOR=ΣCHLOR, and DDT=ΣDDT.

Bird group	Area	*p,p'*-DDE	*p,p'*-DDT	ΣDDT	Mirex
Browsers	Kola Peninsula, n=2	0.23 (0.22-0.25)	<0.05-0.56	0.48-0.91[a]	<0.05
	Pechora basin, n=2	0.24 (0.16-0.36)	<0.05-0.26	0.42-0.65[a]	<0.05
	Taymir, west, n=2	0.19 (0.16-0.23)	<0.05-0.30	0.29-0.68[a]	<0.05
	Taymir, east, n=2	0.24 (0.20-0.29)	<0.05-0.25	0.45-0.95[a]	<0.05
	Chukotka, inland, n=2	0.18 (0.14-0.18)	<0.05-0.24	0.14-0.62[a]	<0.05
	Chukotka, coast, n=2	<0.05-0.05	0.22 (0.19-0.26)	0.31-0.52[a]	<0.05
Grazers	Taymir, west, n=2	3.88 (3.25-4.63)	<0.05	3.45-5.09[a]	0.09 (0.06-0.15)
	Taymir, east, n=2	5.09 (4.52-5.74)	<0.05 - 0.07	5.67-6.12[a]	0.12 (0.07-0.21)
	Chukotka, inland, n=1	0.35	<0.05	0.56	<0.05
Omnivores	Pechora basin, n=4	0.34 (0.23-0.41)	<0.05	0.23-0.67[a]	0.14 (0.13-0.16)[c]
	Taymir, west, n=3	3.47 (1.29-10.1)	0.26 (0.21-0.40)	4.40 (2.11-10.8)	<0.05-0.09
	Taymir, east, n=2	2.43 (1.31-4.50)	0.18 (0.08-0.42)	3.26 (2.17-4.92)	<0.05
	Chukotka, inland, n=3	0.51 (0.26-1.16)	0.29 (0.14-0.49)	1.54 (1.35-1.72)	<0.05
Molluscivores	Kola Peninsula, n=2	1.21 (0.94-1.55)	0.14 (0.11-0.18)	1.59 (1.34-1.89)	<0.05
	Taymir, east, n=2	9.09 (8.56-9.56)	0.25 (0.24-0.26)	10.1 (9.66-10.7)	0.08 (0.08-0.09)
	Chukotka, inland, n=2	1.04 (0.79-1.36)	0.30 (0.23-0.38)	2.47 (2.12-2.90)	<0.05
	Chukotka, coast, n=3	0.35 (0.26-0.50)	0.23 (0.21-0.26)	0.83 (0.67-1.04)[b]	<0.05
Piscivores	Kola Peninsula, n=2	1.26 (1.19-1.33)	0.05 - 0.11	1.25-1.59[a]	0.11 (0.10-0.11)
	Taymir, east, n=1	0.92	0.22	1.44	<0.05
	Chukotka, inland, n=2	0.30 (0.22-0.40)	<0.05	0.31-0.74[a]	0.06 (0.05-0.08)

Table 5.15b. Concentrations (geometric mean and range; ng/g ww) of OCs in the muscle of birds in the Russian Arctic in 2001.
a In at least one sample, more than half of the concentrations were below the detection limit. Concentrations below the detection limit were set to zero or to the detection limit when determining lower and upper limits of concentration ranges.
b The range is given only for oldsquaw (n = 2). Concentrations in eider were below the detection limit.
c The geometric mean and range is given only for pintail (n = 2). Concentrations in mallard are below the detection limit.

were about 1 ng/g ww, about 2-3 times higher than ΣDDT at all sites. Other OCs occurred at concentrations below or close to the detection limit in all samples. As for OCs in reindeer, there was no evident geographical trend for OCs in terrestrial birds.

OC levels in waterfowl are up to an order of magnitude greater that those in browsers. Clear maximum concentrations of all OCs in molluscivores are found in eastern Taymir, near Khatanga. In other bird groups, OC levels at this site are comparable to those found at other sites. Maximum concentrations range from 0.08 ng/g ww for Mirex, and 1-3 ng/g ww for HCB, ΣCHLOR, and ΣHCH, to about 10 ng/g ww for ΣDDT and ΣPCB_{15}. Similar patterns of OC concentrations are seen in other waterfowl at all sites. Concentrations of *p,p'*-DDE found at all sites, are significantly higher than those found in reindeer muscle, while concentrations of other OCs are comparable with those in reindeer. The lowest concentrations occur, as a rule, at sites in Chukotka. Contamination levels in most cases, decrease in the following order: molluscivores > omnivores > piscivores > grazers. All OC concentrations in birds are far below the (maximum) permissible levels for bird meat established in Russia.

(b) PCDD/Fs

Concentrations of 2,3,7,8-substituted PCDD/Fs were analyzed in pooled samples of bird muscle tissue collected from each site. Results are presented in Table 5.16 and Figure 5.12. PCDD/F concentrations in birds follow the same geographic distribution pattern as they do in reindeer, although the spatial differences are less pronounced in birds. All concentrations occur at levels which are far below the maximum permissible levels for these substances in meat.

(c) PAH

Bird tissues were analyzed for the same PAH set as reindeer. Geometric means and ranges of PAH concentrations found in bird muscles in the Russian Arctic in 2001 are given in Table 5.17. Concentrations of 2-methylnaphthalene and fluorene in waterfowl are several times higher, whilst concentrations of phenanthrene and pyrene are several times lower than those found in browsers. Naphthalene and fluoranthene occur in the two bird groups in comparable concentrations. Those PAHs not included in Table 5.17, were found in concentrations close to their detection limits, and then only in few samples of waterfowl. In contrast, chrysene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, benzo[*ghi*]perylene, and biphenyl were detectable in most of the browser muscle samples in concentrations

Species	Area	pg WHO-TEQ/g ww	pg WHO-TEQ/g lipids	pg WHO-TEQ/pg*
Browsers				
Lagopus sp.	Kola Peninsula	0.061	3.1	0.095
	Pechora basin	0.049	2.8	0.130
	Taymir, west	0.038	1.8	0.100
	Taymir, east	0.049	2.2	0.079
	Chukotka, inland	0.020	0.87	0.13
	Chukotka, coast	0.018	1.2	0.16
Molluscivores				
Bucephala clangula	Kola Peninsula	0.17	5.3	0.17
Clangula hyemalis	Taymir, east	0.042	1.9	0.13
	Chukotka, inland	0.052	1.9	0.24
	Chukotka, coast	0.019	0.53	0.078
Omnivores				
Anas acuta	Pechora basin	0.026	1.0	0.093
	Taymir, west	0.11	4.6	0.14

Table 5.16. Concentrations (expressed as TEQ) of PCDD/Fs in bird muscles in the Russian Arctic in 2001.
* – ratio of PCDD/F concentration in pg WHO-TEQ/g to that in pg/g

Bird group	Area	NAP	NAP2M	FLE	PA	FLU	PYR
Browsers	Kola Peninsula, n=2	31 22-43)	7.9 (7.1-8.7)	0.61(0.58-0.65)	21 (18-25)	1.4 (1.2-1.6)	4.3 (3.1-6.1)
	Pechora basin, n=2	35 (19-62)	8.1 (5.2-13)	0.83(0.78-0.88)	25 (16-38)	1.6 (1.3-1.9)	5.2 (5.0-5.6)
	Taymir, west, n=2	28 (23-33)	6.6 (3.5-13)	<0.5-0.89	25 (17-38)	1.5 (1.1-2.0)	4.5 (4.5-4.6)
	Taymir, east, n=2	20 (16-24)	6.2 (2.5-15)	<0.5-1.3	26 (13-52)	1.0 (0.5-1.7)	4.3 (4.1-4.6)
	Chukotka, inland, n=2	35 (30-41)	5.8 (4.2-7.9)	<0.5	37 (16-86)	1.3 (0.84-1.9)	6.1 (4.8-7.8)
	Chukotka, coast, n=2	25 (16-38)	4.7 (3.5-6.2)	<0.5	22 (22-22)	0.75 (0.54-1.0)	5.3 (4.5-6.3)
Grazers	Taymir, west, n=2	6.7 (6.7-7.3)	14 (12-16)	3.7 (3.1-4.5)	5.8 (5.4-6.3)	1.0 (1.0-1.0)	<0.5
	Taymir, east, n=2	9.3 (3.5-25)	21 (19-22)	3.1 (2.8-3.5)	8.3 (6.9-10)	<0.5-0.6	<0.5
	Chukotka, inland, n=1	36	27	4.6	9.2	1.0	<0.5
Omnivores	Pechora basin, n=4	28 (22-40)	14 (4.4-45)	<0.5-5.2	6.8 (4.2-10)	1.2 (1.0-1.4)	<0.5-1.2
	Taymir, west, n=3	12 (5.1-36)	19 (11-25)	2.6 (2.2-3.4)	8.9 (4.4-17)	1.1 (1.0-1.2)	<0.5-1.1
	Taymir, east, n=2	44 (26-73)	22 (15-32)	<0.5-2.0	5.6 (4.5-6.8)	1.4 (1.2-1.6)	<0.5-1.0
	Chukotka, inland, n=3	25 (20-37)	6.7 (4.1-8.9)	2.7 (2.1 –3.5)	5.2 (4.6-6.2)	2.3 (1.9-2.6)	<0.5-1.4
Molluscivores	Kola Peninsula, n=2	24 (22-26)	10 (6.4-16)	1.6 (1.3-2.0)	5.5 (5.3-5.7)	1.9 (1.8-2.1)	1.1 (1.0-1.2)
	Taymir, east, n=2	25 (21-31)	24 (21–28)	3.4 (2.4 – 4.9)	7.3 (7.1-7.6)	<0.5-1.1	<0.5
	Chukotka, inland, n=2	17 (16-18)	7.0 (5.3-9.3)	<0.5 – 1.2	3.7 (3.0-4.7)	1.3 (0.93-1.7)	<0.5
	Chukotka, coast, n=3	7.0 (2.0-14)	11 (7.1-20)	2.8 (2.2 –3.8)	4.3 (2.4-8.4)	1.1 (<0.5-2.7)	1.0 (<0.5-2.2)
Piscivores	Kola Peninsula, n=2	20 (13-31)	19 (14-27)	4.9 (4.3-5.5)	7.7 (6.1-9.6)	0.90 (0.81-1.0)	<0.5
	Taymir, east, n=1	28	14	3.4	6.0	2.3	1.1
	Chukotka, inland, n=2	29 (25-34)	38 (29-50)	4.5 (4.5-4.5)	8.1 (7.5-8.7)	0.79 (0.63-1.0)	<0.5

Table 5.17. Concentrations (geometric mean and range; ng/g ww) of PAHs a in muscle of birds in the Russian Arctic in 2001.
[a] NAP = Naphthalene, NAP2M = 2-Methylnaphthalene, FLE = Fluorene, PA= Phenanthrene, FLU = Fluoranthene, PYR = Pyrene

Bird group	Area	Hg	Pb	Cd
Browsers	Kola Peninsula, n=2	<0.001	0.14 (0.10-0.22)	0.056 (0.042-0.074)
	Pechora basin, n=2	<0.001	0.20 (0.14-0.29)	0.067 (0.063-0.072)
	Taymir, west, n=2	<0.001	0.24 (0.16-0.37)	0.091 (0.061-0.13)
	Taymir, east, n=2	<0.001	0.11 (0.07-0.18)	0.049 (0.045-0.053)
	Chukotka, inland, n=2	<0.001	0.09 (0.07-0.12)	0.047 (0.036-0.061)
	Chukotka, coast, n=2	<0.001	0.11 (0.08-0.18)	0.050 (0.038-0.066)
Grazers	Taymir, west, n=2	0.012 (0.011-0.013)	0.057 (0.054-0.060)	0.006 (0.004-0.008)
	Taymir, east, n=2	0.006 (0.006-0.006)	0.09 (0.07-0.11)	0.010 (0.005-0.021)
	Chukotka, inland, n=1	0.010	- [a]	0.028
Omnivores	Pechora basin, n=4	0.062 (0.035-0.12)	0.13 (0.11-0.17)[a]	0.012 (0.005-0.036)
	Taymir, west, n=3	0.037 (0.019-0.10)	0.31 (0.27-0.35)	0.034 (0.031-0.037)
	Taymir, east, n=2	0.065 (0.059-0.071)	0.067 (0.047-0.095)	0.004 (0.003-0.005)
	Chukotka, inland, n=3	0.019 (0.012-0.043)	0.43 (0.15-1.2)	0.013 (0.008-0.019)
Molluscivores	Kola Peninsula, n=2	0.10 (0.10-0.11)	0.52[a]	0.030 (0.011-0.085)
	Taymir, east, n=2	0.073 (0.063-0.085)	0.35 (0.22-0.57)	0.069 (0.050-0.096)
	Chukotka, inland, n=2	0.027 (0.026-0.029)	0.23 (0.22-0.24)	0.015 (0.013-0.018)
	Chukotka, coast, n=3	0.055 (0.050-0.064)	0.12 (0.08-0.18)	0.020 (0.017-0.032)
Piscivores	Kola Peninsula, n=2	0.064 (0.046-0.090)	0.11 (0.10-0.12)	0.020 (0.019-0.021)
	Taymir, east, n=1	0.034	0.21	0.003
	Chukotka, inland, n=2	0.080 (0.073-0.086)	0.21[a]	0.012 (0.011-0.013)

Table 5.18. Concentrations (geometric mean and range; µg/g ww) of HMs in muscle of birds in the Russian Arctic in 2001.
[a] Data for one sample which was contaminated by lead shot was discarded. Pb concentrations in contaminated samples range from 0.5 to 11 µg/g wet weight.

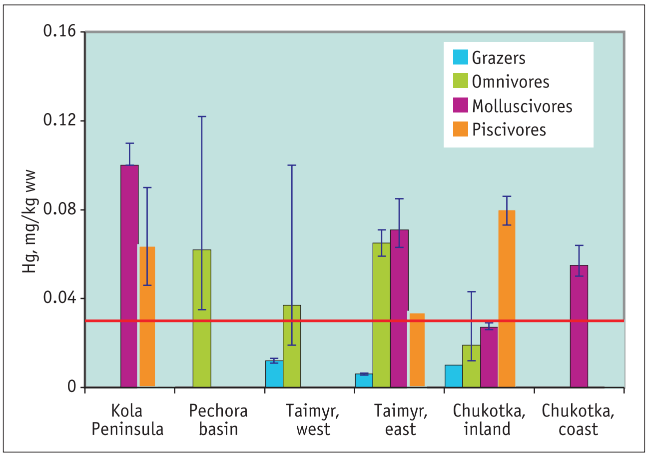

Figure 5.16. Geometric means and ranges of Hg concentrations in muscle of waterfowl in the Russian Arctic in 2001. The red line indicate the maximum permissible concentrations of Hg allowed by food safety standards. The number of values used for calculating means varied between 1 and 4.

from 0.5 to 5 ng/g ww. Levels of all PAHs in browsers, with the exception of fluorene, were about twice as high as those found in reindeer. No noticeable geographic trend was observed for any of the PAHs. For these substances, the variability between samples was always comparable with the variability between sites.

(d) Brominated flame-retardants

Samples of bird tissues were analyzed for 2,2',4,4'-tetrabromodiphenyl, 2,2',4,4',5-pentabromodiphenyl, 2,2',4,4'-tetrabromodiphenyl ether, and 2,2',4,4',5-pentabromodiphenyl ether. In all samples, these substances were found at concentrations below the detection limit of 0.2 ng/g ww.

(e) Heavy metals

In most of the waterfowl samples, levels of Hg exceeded the MPC for this metal, and only in browsers were Hg concentrations below the detection limit at all sites (see Figure 5.16). Levels of Pb and Cd in terrestrial birds and waterfowl are comparable (see Table 5.18). No pronounced geographic trend was observed for any of the HMs in any bird group. Concentration differences occurring between any two sites, for a given HM and bird group, were not statistically significant, despite inter-sample variability being quite low at almost all sites. The only notable exception to this, was the concentration of Cd measured in omnivores and piscivores in eastern Taymir, which was found to be significantly lower than at other sites. Concentrations of Pb and Cd in birds were normally below maximum permissible levels for these metals (0.5 and 0.05 mg/kg, respectively), and only in few samples were concentrations found to be higher (up to twice the MPC level).

5.3.5. PTS transfer in the terrestrial food chain

For the estimation of soil-to-lichen and water-to-fish transfer coefficients, pooled samples of soil were collected at all 6 sites. The number of pooled samples ranged from 1 to 5, and the number of single samples used in the preparation of pooled samples ranged from 3 to 9 (see Table 5.1). Most of the soils sampled were of peat litter.

(a) Organochlorines

It is well known that POPs that are present in abiotic media (soil, water and air) can be taken up by living organisms, and subsequently transferred within food chains. In most cases, intake via the diet is the major pathway for human POP exposure. In a steady state system, POPs are distributed throughout the environment according to the fugacity capacities of the various environmental compartments. For POPs, fugacity capacities are proportional to the lipid concentration in a given biological compartment (Sharpe and Mackay, 2000; McLachlan, 1996). In this section, the partitioning of OCs between abiotic media and the tissues of terrestrial organisms in the Russian Arctic is considered, mainly using data on *p,p'*-DDT and *p,p'*-DDE levels. These two OCs, are convenient reference compounds, being detectable in most biotic and abiotic samples collected. In addition, the ratio of *p,p'*-DDE to *p,p'*-DDT levels in soil is widely used to estimate the age of the contamination and can, therefore, serve as an indicator of the relative rate of *p,p'*-DDT metabolic transformation in organisms. Most other OCs follow similar patterns of uptake and transport in food chains that have been studied.

The soil-lichen-reindeer food chain is one of the most important in the Arctic. An example of levels of *p,p'*-DDT and *p,p'*-DDE in this chain are given for Khatanga in eastern Taymir in Figure 5.17. Geometric means of soil-to-lichen transfer factors (concentration ratios) for both *p,p'*-DDT and *p,p'*-DDE are equal to 2.9 ranging from 0.7 (for *p,p'*-DDT on the Kola Peninsula) to 15 (for *p,p'*-DDE in western Taymir). The soil-to-lichen transfer factors for other OCs show a similar degree of variability and similar geometric means (1.1 for PCB-28 and PCB-153, 1.9 for HCB, and 2.5 for HCH isomers). High levels of within site variability in the ratios are most probably explained by a relatively high variability of *p,p'*-DDT and *p,p'*-DDE concentrations in soils. Variability in OC concentrations at a particular site is significantly less in lichens and mosses than soils. Lichens and mosses uptake pollutants primarily from the air, which, in the absence of local sources of pollutants, has relatively uniform contamination levels.

Even though lichens do not take up OCs directly from the soil, soil-to-lichen transfer coefficients can still be calculated, is based on the fact that, in the air of remote areas, OC levels are proportional to those in soil, especially surface soil. Proportionality of OC levels between soils and lichens can, therefore, also be expected. Uptake from the air is the main route by which POPs contaminate, not only mosses and lichens, but also other plants; as POPs are highly lipophilic compounds and, once adsorbed on the root surfaces, they tend not to be translocated to the aboveground parts of plants (McLachlan, 1996). Concentrations of OCs in air were not measured in the current study, therefore, only relative air-to-plant transfer factors (based on interspecies concentration ratios) could be calculated. Using such ratios, once the OC concentration has been measured in one particular plant species at a given site, the concentration in any other species can be estimated using the corresponding species/ species concentration ratio.

This approach relies on the similarity of the uptake mechanism for POPs in different plant species. The predominant pathway for uptake of POPs by plants is dry gaseous deposition from the atmosphere (Paterson *et al.*, 1994; McLachlan, 1996). The POP concentration in plants (C_P) can be related to that in air (C_A) by the following equation:

$$C_P = L \cdot K_{OA} \cdot C_A \qquad (5.1)$$

where:

L is the lipid fraction in the plant tissue (volume/volume);

K_{OA} – is the octanol-air partition coefficient (the ratio of volume concentrations when at equilibrium).

Taking into account of the relatively low variability in lipid content in plant tissues, Equation 5.1 indicates that POP concentration ratios between two species can be considered as being independent of site. If the kinetic limitations of uptake and depuration are ignored, it could also be expected that the same ratio value would apply for all POPs. A comparison of the concentrations of all OCs (excluding PCB) in lichens and mosses supports these assumptions (see Figure 5.18). From Figure 5.18, it is evident that OC concentrations in lichens show a clear relationship to those in mosses. The best correlation is seen for DDT metabolites, probably because these contaminants are present at higher concentrations and there is a lower detection error. The lichen/moss concentration ratio for POPs, obtained using linear regression analysis, is equal to 0.97. In other words, POPs concentrations in lichen can be used as a direct estimate of the POP concentrations in mosses in the study area, and vice versa.

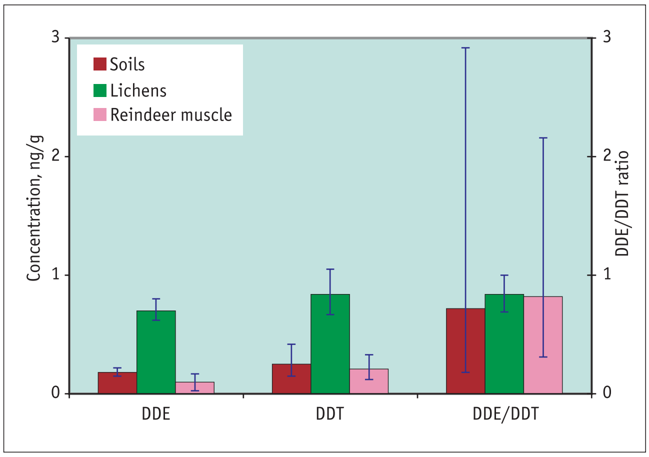

Figure 5.17. Absolute and relative levels of *p,p'*-DDE and *p,p'*-DDT for the soil-lichen-reindeer food chain in the Khatanga area. Geometric means and ranges of DDE and DDT levels in soil and lichen are provided on a dry weight basis, while levels in reindeer muscle are on a wet weight basis; 95% confidence limits are shown for ratios.

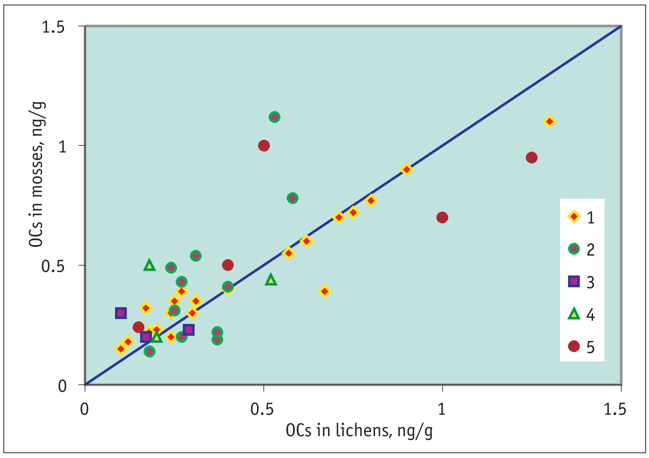

Figure 5.18. The relationship between OC concentrations in mosses and lichen (dry weight) in the northern Russia. 1 – DDT and its metabolites, 2 – HCH isomers, 3 – Heptachlor, 4 – Mirex, 5 – HCB.

Berries and mushrooms are both components of the human diet in the Russian North. Assessment of their contribution to human OC exposure in the Arctic requires data on contamination levels. As the available data set for berry and mushroom contamination in the Arctic is much more limited than that for lichen and mosses, the calculated lichen/berry and lichen/mushroom concentration ratios are useful. Sufficiently reliable data for calculation of the berry/lichen concentration ratio were obtained only for *p,p'*-DDT and HCB (although data for the Kola Peninsula site where an anomalously high *p,p'*-DDT level was measured were excluded). The berry/lichen concentration ratio for *p,p'*-DDT was found to be practically the same as that for HCB. The geometric mean of the nine ratios calculated, using data on both *p,p'*-DDT and HCB, is equal to 0.27.

Lichen-to-reindeer transfer factors (TF_{LR}) were also of the same value (0.3, based on wet wt. and dry wt. concentrations, respectively) for both *p,p'*-DDT and *p,p'*-DDE. They ranged from 0.1 (for *p,p'*-DDE in western Taymir) to 1.8 (for *p,p'*-DDE in Chukotka). In the Canadian Arctic, in 1993, this factor was found to range from one to values in the tens (based on lipid wt. and dry wt. concentrations, respectively) for different OCs (CACAR, 1997). The geometric mean of lipid content measured in reindeer muscle in the current study was about 5%. Using this value to convert the transfer factors based on wet wt. concentrations to their lipid wt. equivalents yields values that are close to those reported for Canada. TF_{LR}s for other OCs that were found at concentrations above detection limits in the current study are of similar values to those determined for *p,p'*-DDT and *p,p'*-DDE (0.2 for PCB-28, 0.8 for PCB-153, 0.5 for α- and γ-HCH, and 0.3 for HCB, based on wet wt. and dry wt. concentrations, respectively).

All transfer factors obtained for *p,p'*-DDT and *p,p'*-DDE in the soil-lichen-reindeer chain agree reasonably well with the values expected on the basis of corresponding concentration ratios for lipids. This result is reasonable since POP concentrations in the soil surface and in plants will generally be at close to equilibrium with POP concentrations in the air, and will reflect the lipid contents of the soil and plants (McLachlan, 1996). Relatively large deviations from equilibrium are observed only for concentrations of POPs which have a very high molecular weight, but even then, these deviations are similar in both plants and soils. POP absorption and depuration by mammals is significantly slower than that by plants. For example, the depuration half-life for PCDD in the human body can be as long as several years (Masuda, 2001). However, given relatively stable levels of air contamination, POP concentrations in mammal tissues and in vegetation used for food should, in general, be comparable, after correction for lipid content (McLachlan, 1996). For example, cow milk/fodder fugacity quotients measured in Germany were, with a few exceptions, close to unity for HCB, PCBs, and PCDD/Fs (McLachlan, 1996). This indicates that a steady state partitioning of OCs between feed and cow tissues takes place. Data obtained in the current study indicated that OC distribution between soil, lichen, and reindeer tissues was also close to a steady state. The observed lack of dependence of OC concentrations in reindeer tissues on animal age, and also the similarity of values calculated for OC concentration and lipid content ratios for reindeer/hare and reindeer/birds also support this conclusion (see Figure 5.19). All differences found between reindeer/hare and reindeer/bird concentration ratios for lipids and any of the OCs were small and within a factor of two, and OC ratio ranges agreed closely with those for lipids.

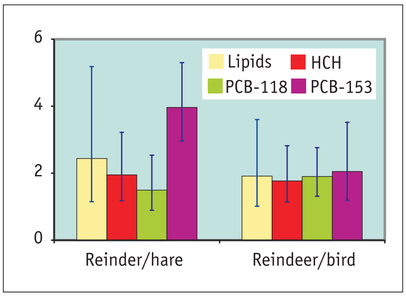

Figure 5.19. Concentration ratios (geometric mean and 95% confidence limits) for OCs and lipid content in reindeer/hare and reindeer/birds, for all sample sites.

The DDE/DDT ratio in soils immediately following application of DDT pesticide is normally about 0.1 or less (Harner *et al.*, 1999). As a result of the microbiological transformation of *p,p'*-DDT into *p,p'*-DDE, and other metabolites, this ratio increases with time. In temperate zones, the DDE/DDT ratio in soils 30 years after the last pesticide application ranges from 0.7 to 2 (Harner *et al.*, 1999). Ratios in the Russian Arctic are, as a rule, at the lower end of this range (see Table 5.19a). This may indicate that fresh use of DDT is still contributing to contamination of the Russian Arctic. However, lower ratio values can be also explained by the slower rate of metabolic processes which occur in Arctic soils.

Metabolic transformation of *p,p'*-DDT also takes place in higher organisms (WHO, 1982) and the DDE/DDT ratio in their tissues can serve as an indicator of the relative rate of *p,p'*-DDT transformation in different species. DDE/DDT ratios in terrestrial food chains in the Russian Arctic are provided in Figure 5.17 and Tables 5.19a and 5.19b. No statistically significant differences were observed between the ratio values, either in soils, lichens, or reindeer tissues, or, between the 6 sites (see Table 5.19a and 5.19b). This indicates that the *p,p'*-DDT transformation rate in reindeer tissues is comparable with that in soils and lichens. The ratio values for terrestrial birds are, as a rule, somewhat higher than in reindeer (see Table 5.19a), probably due to a faster rate of metabolic *p,p'*-DDT transformation in birds.

(b) Heavy metals

Some HMs, such as copper (Cu) and zinc (Zn) are essential elements for both plants and animals and as such, their levels in tissues are under homeostatic control (Yagodin *et al.*, 1989; Speidel and Agnew, 1982).

Table 5.19a.
DDE/DDT ratios (geometric means and 95% confidence interval) in terrestrial food chains.
n. d. – not detected

Site	Soil	Lichens	Browsers	
			Muscle	Liver
Kola Peninsula	0.35 (0.26-0.49)	0.60 (0.49-0.73)	0.39	4.2 (0.84-21)
Pechora basin	0.53 (0.4-0.69)	0.28	3 (0.14-65)	2.2 (0.69-3.2)
Taymir, west	0.54 (0.46-0.63)	0.87 (0.28-2.78)	0.77	1.4 (1.30-1.6)
Taymir, east	0.72 (0.18-2.9)	0.84 (0.69-1.0)	3.1 (0.22-41)	2.1 (0.63-7.4)
Chukotka inland	2.4	0.49 (0.33-0.74)	0.75	0.76 (0.76-0.77)
Chukotka, coast	0.48	0.44	0.19	n.d.
All sites	0.52 (0.48-0.71)	0.64 (0.54-0.74)	1.2 (0.14-10)	1.9 (0.6-5.7)

Non-essential elements, such as Hg and Cd, do not appear to be well-regulated by living organisms. Thus, tissue concentrations of Hg and Cd proportional to environmental (or food) contamination levels can be expected. The use of transfer factors is based on this assumption. However, deviations from direct proportionality do occur, and quite often are more pronounced at higher levels of exposure, especially for Pb (WHO 1989a, 1989b, 1991, 1992, 1995). A possible explanation for this is that HMs in high concentrations are toxic for all organisms and their transfer through cell membranes may be limited when tissue contamination exceeds some critical level. In addition, Pb content in tissue is probably under at least some degree of homeostatic regulation, since it belongs to a group of so-called 'conditionally essential elements' (Yagodin *et al.*, 1989; Speidel and Agnew, 1982). As a result, the HM transfer coefficient for a particular link in a food chain depends not only upon environmental conditions, but also upon the HM concentration in abiotic media (or food). It follows that use of HM transfer coefficient values obtained at low exposure levels, for tissue concentration assessment at high exposure levels, can lead to an overestimation of the concentration of that HM.

Another important condition for the applicability of the transfer factor approach, is the absence of kinetic limitations. The biological half-life of HMs in mammals is difficult to estimate (WHO 1989a, 1989b, 1991, 1992, 1995). The biological half-life of Hg and Pb in blood and the soft tissues of mammals normally ranges from several weeks to several months. However, significantly slower Hg and Pb elimination rates have also been reported. For example, the half-life of Hg in brain tissue and of Pb in bone ranges from years to decades, and for a mammal to eliminate 50% of absorbed Cd can take as long time as 30 years. Based on these elimination rates, HM food-to-mammal transfer factors can be expected to show a significant degree of dependence on mammal age.

As for OCs, the soil-lichen-reindeer food chain is one of the most important pathways for human exposure to HMs in the Arctic. Lichen is able to assimilate mineral substances from any material to which it adheres. However, the similar pattern of HM concentration ratios in lichens, mosses and soils (Hg: Cd: Pb in the ratio of 2:3:95) indicates that mosses, as well as lichen, take up most of their HM burden from the air, apparently from windblown soil and dust. Geometric mean values of lichen/moss concentration ratios ranged from 0.5 to 0.6 for all three HMs. This ratio can be considered indicative of the greater ability of mosses to intercept particles. The geometric mean for the lichen/moss concentration ratio, calculated using the pooled set of data for all three metals was equal to 0.56.

An example of HM concentration patterns for the soil-lichen-reindeer food chain is given in Figure 5.20.

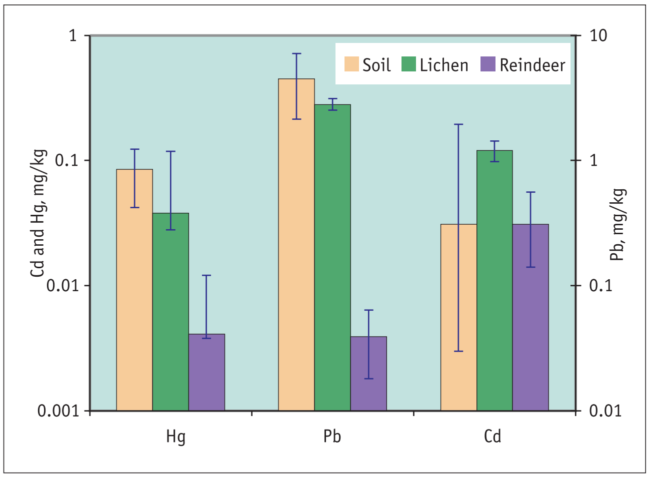

Figure 5.20. HM distribution patterns in the soil-lichen-reindeer food chain on the Kola Peninsula in 2001. Concentrations of HMs in soil and lichen and their ranges are given on the dry weight basis, while those for reindeer muscle are provided on the wet weight basis.

Table 5.19b.
DDE/DDT ratios (geometric means and 95% confidence interval) in terrestrial food chains.
n. d. – not detected

Site	Reindeer		
	Muscle	Liver	Kidney
Kola Peninsula	0.63 (0.38-1.1)	1.3 (0.67-2.4)	0.93 (0.54-1.6)
Pechora basin	0.39 (0.21-0.73)	1.2 (0.75-1.8)	0.83 (0.53-1.3)
Taymir, west	0.55 (0.35-0.85)	0.47 (0.23-0.96)	0.72 (0.58-0.88)
Taymir, east	0.82 (0.31-2.16)	0.38 (0.12-1.2)	0.41 (0.13-1.3)
Chukotka inland	1.33 (0.67-2.6)	0.5	n.d.
Chukotka, coast	1.5 (1.43-1.58)	0.49 (0.46-0.51)	n.d.
All sites	0.65 (0.48-0.89)	0.76 (0.54-1.1)	0.73 (0.55-0.96)

Soil-to-lichen transfer coefficients for Hg and Pb are similar (the geometric mean equal to 0.6, ranging from 0.3 to 1.3 based on dry wt. concentrations). The geometric mean for Cd was about twice as high (1.3), but the difference is of low statistical significance. Soil-to-lichen transfer factors for HMs are several times lower than those for OCs. This is consistent with the hypothesis that soil dust interception is the main pathway of HM uptake by lichens, whilst organic chemicals, in addition to this mechanism, are also absorbed through dry gaseous deposition. Uptake of HMs from soil by mushrooms is more strongly affected by the chemical state of the metal. Geometric mean values of soil-to-mushroom transfer factors (based on dry weight concentrations) ranged from 0.12 and 0.25 for Pb and Hg, respectively, to 1.5 for Cd. The geometric mean of the soil-to-berry transfer factor for Pb (0.006) is two orders of magnitude lower than that calculated for lichens.

Significant differences between Pb and Hg and Cd also occur in the transfer of HMs from lichen to reindeer tissues. Geometric means of lichen-to-reindeer transfer factors for Hg and Cd are similar (0.4 and 0.5, respectively) and an order of magnitude higher than that calculated for Pb (0.03). All transfer factors as a function of herd, vary within an order of magnitude. This variability can be partially explained by differences in the mean age of animals sampled. The age dependence of a pollutant concentration in an animal tissues can be described by the following simple model:

$$\frac{dC}{dt} = r_i - k_e C \qquad (5.2)$$

Where:

C is the pollutant concentration in the animal, ng/g ww;
r_i is the pollutant accumulation rate, ng/g ww per year;
k_e is the pollutant elimination rate constant, per year;
t is the animal age, years.

Assuming that the intake rate is constant, this can be expressed as:

$$C = \frac{r_i}{k_e}(1 - e^{-kt}) \qquad (5.3)$$

When $k_e t$ is small (i.e., elimination is slow), equation 5.4 can be simplified and the concentration dependence on age becomes directly proportional:

$$C = r_i t \qquad (5.4)$$

As was shown in section 5.3.2, HM levels in reindeer are directly proportional to age. This means that the elimination rate is quite slow ($k_e t$ is small) during at least the first few years of life, and effective rates of HM accumulation in reindeer tissue (see Table 5.12) provide an estimate of r_i. Values for the elimination rate (k_e) can be estimated by applying equation 5.3 to experimental data. Because of the small number of age groups and narrow age intervals recorded, the accuracy of such estimates using data obtained in this study is low. However, it is clear that the elimination half-life for all three HMs is at least several years, and could be in the order of 10 years.

Using a typical rate of lichen consumption by reindeer (i.e. 40 g dw/kg live weight per day; White *et al.*, 1999) and HM concentrations from Table 5.7, the total annual uptake of HMs from lichen by reindeer can be calculated. Based on geometric means, this yields values of 0.51, 29, and 1.0 mg/kg live weight per year for uptake of Hg, Pb and Cd, respectively. Comparison of these values with effective deposition rates from Table 5.12 indicate that less than 0.1% of Pb from consumed lichens is transferred into the muscle, while the effectiveness of Hg and Cd transfer to muscle is up to an order of magnitude greater, with values of 0.4% and 1.0%, respectively.

5.4. Freshwater environment

5.4.1. PTS in fish

Fish were obtained from Lake Lovozero (Kola Peninsula), the Pechora River, the Yenisey River (western Taymir), the Khatanga River (eastern Taymir), and the Kanchalan River (inland Chukotka). Fish age ranged from 5 to 14 years. The number of individual samples of tissue collected at a given location for use in the preparation of pooled samples ranged from 1 to 13 (see Table 5.1). The following fish species were sampled:

- pike (*Esox lucius*)
- burbot (*Lota lota*)
- perch (*Perca fluviatilis*)
- ide (*Leuciscus idus*)
- whitefish (*Coregonus lavaretus*)
- Arctic cisco (*Coregonus autumnalis*)
- broad whitefish (*Cerogonus nasus*)
- Arctic char (*Salvelinus alpinus*)
- inconnu (*Stenodus leucichthys nelma*)
- grayling (*Thymallus thymallus*)

Fish muscle and liver tissues were analyzed for all PTS listed in Section 1.2.4. Results of analysis were divided into groups according to sex (male or female), age (either two or three classes), and tissue type (muscle or liver). Age differences within groups ranged from 1 to 2 years. The difference between the mean ages of fish in the oldest and youngest groups was always less than a factor of two.

PTS concentration relationships to fish sex, age and tissue type

(a) Organochlorines

Male/female concentration ratios of OCs that could be reliably quantified (*p,p'*-DDT, *p,p'*-DDE, PCB-138, PCB-153, and HCB) were calculated using data from fish of the same age groups. No statistically significant difference was found between the geometric mean of the ratios and unity, for any OCs or any species. Calculated age ratios (for middle/young and old/young age groups) are, with a few exceptions, slightly higher than unity and range from 0.8 to 2.8. However, in all cases, the standard deviation was comparable to, or larger than the mean ratio value. Taking into account the relatively small number of values included in the average, this implies that the statistical significance of any observed age dependency is very low, and that data for all age groups can be combined in the calculation of geometric mean OC concentrations. The geometric means of OC liver/muscle concentration ratios are close to unity for salmon species and range from 2 to 5 for pike, perch and ide. The highest absolute and relative concentrations of all OCs from all sites were found in burbot liver samples. In the liver of both male and female burbot, fished from Yenisey River, OC concentrations were as high as 580 ng/g for ΣPCB_{15}, 470 ng/g for ΣDDT, and 39 ng/g for ΣCHLOR. Levels of OCs in the liver of other fish species were much lower. In contrast, OC concentrations in burbot muscle were very close to those in other species. The liver/muscle concentration ratio for burbot varied from site to site within two orders of magnitude. The geometric mean for detected OCs in burbot ranges from 50 to 160. These observations are explained by the fact that the lipid content of burbot liver is significantly higher than that of the other species studied, whilst lipid levels in the muscle

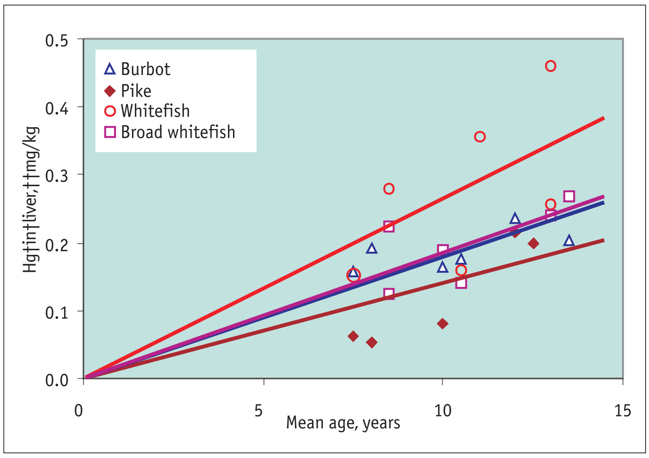

Figure 5.21. Hg concentration in fish liver as a function of the fish age in northern Russia in 2001.

Table 5.20.
Geometric means and 95% confidence interval of effective rates of accumulation of heavy metals in fish tissues (µg/g ww per year).

Fish	Area	Muscle	Liver
		Hg	
Burbot	Kola Peninsula, n=4	0.018 (0.013-0.024)	0.043 (0.037-0.049)
	Taymir, west, n=6	0.011 (0.0088-0.013)	0.019 (0.016-0.021)
	Taymir, east, n=4	0.010 (0.072-0.14)	0.020 (0.014-0.029)
Pike	Kola Peninsula, n=4	0.017 (0.013-0.023)	0.035 (0.031-0.039)
	Chukotka, inland, n=6	0.0058 (0.0039-0.088)	0.012 (0.0080-0.017)
Perch	Pechora basin, n=3	0.012 (0.011-0.013)	0.025 (0.020-0.031)
Ide	Pechora basin, n=5	0.0069 (0.0053-0.089)	0.013 (0.011-0.016)
Whitefish	Kola Peninsula, n=4	0.014 (0.013-0.015)	0.043 (0.034-0.054)
	Pechora basin, n=5	0.0053 (0.0046-0.0060)	0.013 (0.011-0.014)
	Taymir, west, n=4	0.0069 (0.0048-0.010)	0.017 (0.014-0.020)
	Taymir, east, n=6	0.014 (0.0066-0.030)	0.025 (0.019-0.033)
Arctic cisco	Taymir, west, n=4	0.0039 (0.0030-0.0052)	0.011 (0.010-0.013)
Broad Whitefish	Taymir, east, n=6	0.0075 (0.0066-0.086)	0.018 (0.015-0.022)
Inconnu	Chukotka, inland, n=2	0.0031 (0.0028-0.0036)	0.014 (0.089-0.022)
		Pb	
Burbot	Kola Peninsula, n=4	0.0051 (0.0040-0.0064)	0.019 (0.014-0.0025)
	Taymir, west, n=6	0.015 (0.011-0.022)	0.025 (0.021-0.030)
	Taymir, east, n=4	0.0037 0.0017-0.0081)	0.010 (0.0054-0.017)
Pike	Kola Peninsula, n=4	0.012 (0.0099-0.015)	0.046 (0.040-0.052)
	Chukotka, inland, n=6	0.018 (0.016-0.021)	0.044 (0.037-0.052)
Perch	Pechora basin, n=3	0.020 (0.016-0.026)	0.057 (0.044-0.074)
Ide	Pechora basin, n=5	0.0031 (0.0027-0.0036)	0.013 (0.011-0.016)
Whitefish	Kola Peninsula, n=4	0.0014 (0.0010-0.0019)	0.013 (0.012-0.015)
	Pechora basin, n=5	0.0014 (0.0012-0.0017)	0.016 (0.013-0.020)
	Taymir, west, n=4	0.0033 (0.0028-0.038)	0.022 (0.018-0.028)
	Taymir, east, n=6	0.0016 (0.0009-0.0030)	0.021 (0.018-0.025)
Arctic cisco	Taymir, west, n=4	0.0021 (0.0020-0.0023)	0.012 (0.0081-0.017)
Broad Whitefish	Taymir, east, n=6	0.00083 (0.0006-0.0011)	0.021 (0.018-0.025)
Inconnu	Chukotka, inland, n=2	0.0089 90.0067-0.012)	0.028 (0.021-0.38)
		Cd	
Burbot	Kola Peninsula, n=4	0.0037 (0.0029-0.0045)	0.024 (0.019-0.030)
	Taymir, west, n=6	0.0032 (0.0022-0.0045)	0.019 (0.015-0.026)
	Taymir, east, n=4	0.0052 (0.0026-0.010)	0.011 (0.010-0.0014)
Pike	Kola Peninsula, n=4	0.037 (0.0032-0.0042)	0.021 (0.015-0.028)
	Chukotka, inland, n=6	0.0028 (0.022-0.0036)	0.0084 (0.0075-0.0095)
Perch	Pechora basin, n=3	0.0043 (0.0034-0.0053)	0.018 (0.015-0.022)
Ide	Pechora basin, n=5	0.0026 (0.0020-0.0032)	0.023 (0.020-0.028)
Whitefish	Kola Peninsula, n=4	0.0032 (0.0027-0.0038)	0.024 (0.021-0.028)
	Pechora basin, n=5	0.0020 (0.0015-0.0025)	0.015 (0.012-0.019)
	Taymir, west, n=4	0.0019 (0.0014-0.0027)	0.0080 (0.0073-0.0088)
	Taymir, east, n=6	0.0018 (0.0012-0.0027)	0.017 (0.013-0.023)